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UNITED STATES DEPARTMENT OF AGRICULTURE
AGRICULTURAL RESEARCH ADMINISTRATION
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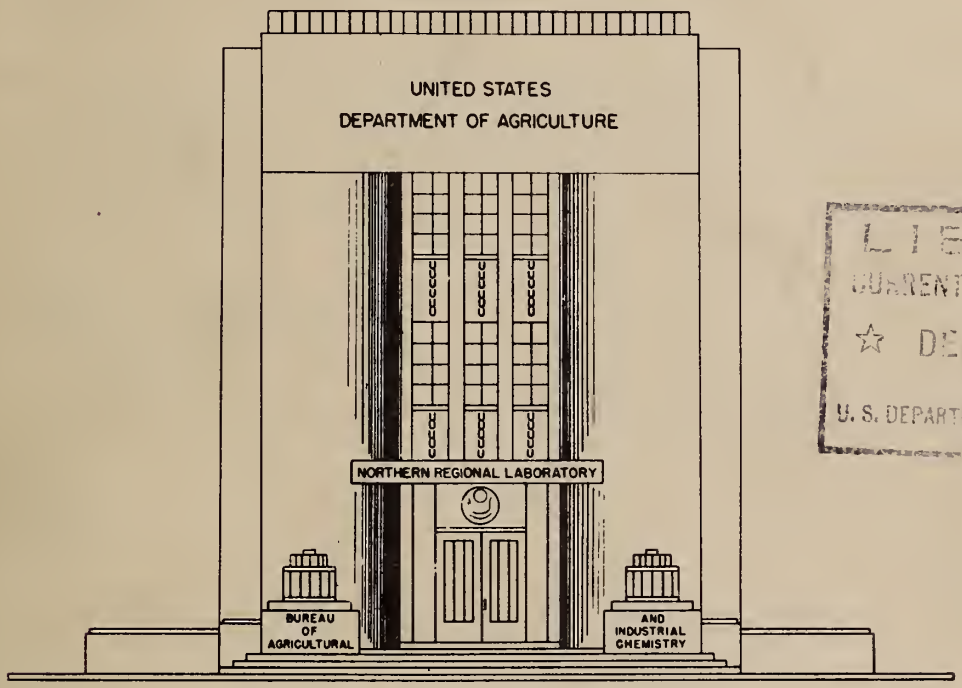
A SELECTED AND ANNOTATED BIBLIOGRAPHY ON SOFT CORN AND PERTINENT INFORMATION ON THE DRYING, PRESERVATION, AND STORAGE BEHAVIOR OF CORN AND OTHER GRAINS



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PART I. SOFT CORN

Definition

Richey, Frederick D.- Handling the soft corn crop. U. S. Dept. Agr. Dept. Cir. 333. 1924.

"The term soft corn can be applied properly to any corn that is soft and watery, in contrast to the relatively hard, dry kernels of ears as they are cribbed under ordinary conditions." *** "Soft corn will vary from that which is mature but not dry to very immature and watery corn." *** "In the normal progress of the corn crop, the plants mature some two or three weeks ahead of a killing frost. At the time of maturity the grain contains between 35 and 40 percent of moisture. Following this there is a gradual loss of moisture from the whole plant, until at husking time the moisture content of the grain usually is about 20 percent." The last quotation most likely is a description of the ordinary conditions referred to in the preceding quotations.

Evvard, John M.- The soft corn problem. Ia. Agr. Exp. Sta. Cir. 40. 1917.

"What is soft corn? Generally speaking, soft corn is corn that runs anywhere from 25 to 65 percent moisture. Sometimes, however, corn with a moisture content under 25 percent may be considered as relatively soft corn, when compared to hard, mature corn."

Physical and Chemical Characteristics

Bushey, Alfred.- Some chemical characteristics of soft corn. S. Dakota, Bul. 210. 1924.

The findings reported here indicate that feeding soft corn sometimes is not successful. Chemical analysis of frosted and normal corn shows that there is little difference in their total crude protein. Frosted corn contains a higher percent of ash, similar starch, high crude fiber, and a varying oil (ether extract) content.

The protein of corn is made up of a number of compounds, i.e., amide nitrogen, albumens, globulins, glutelin, and zein. Of these, glutelin and globulin are said to be complete proteins in that they furnish all the amino acids necessary for growth and maintenance, while in zein at least two amino acids, namely, lysine and tryptophane, are said to be absent. Amide nitrogen is usually assumed to have no nutritive value. The chemical analysis of the frosted samples showed them to be high in amide, albumin, and globulin nitrogen; low in glutelin, with a variable zein content. With this structure the feeding value would be questionable.

The stage of maturity at which the injury occurs probably determines more than any other factor the value of the produce.

Evvard, John M.- The soft corn problem. Ia. Agr. Exp. Sta. Cir. No. 40. 1917.

The author gives the following information taken from a bulletin by Jones and Huston (Ind. Agr. Exp. Sta. Bul. 175).

"In the early kernel stage, less than 15 percent of the dry matter found at maturity is yet laid down in the ear, and only 44 percent in the milk stage. If frost comes when the milk still shows plainly, the yield is approximately half in dry matter, as compared to the normal matured yield. The stover (without ears) contains more than 90 percent of the total possible dry matter as early as the milk stage, this demonstrating that in frosted corn the greatest damage in yield is to the ears, which are really 'nipped in the bud', and not allowed to develop.

"The chemical feed constituents in 100 pounds of dry matter of the ear corn, cob and all, at the different stages as figured from Indiana results (Bul. Ind. Agr. Expt. Sta. 175), of Jones and Huston are given herewith: *** "

Stage of growth	Moisture in ear when husked	Protein	Carbohydrates, starches, sugars, etc.	Crude fiber	Fat	Minerals	Pounds fat formers with every pound of protein
Four feet high, July 24							
First tassels, Aug. 6							
Silks drying, kernels forming, Aug. 28	84.40	13.47	62.72	3.03	.19	.49	6.30
In the milk, Sept. 10	68.89	11.10	72.67	3.61	.75	.69	8.07
In the glaze, Sept. 24	55.15	8.94	77.20	3.62	1.83	.76	10.54
Well dented, Oct. 1	50.23	9.73	77.83	3.49	1.93	.77	9.60
Ready to shock, Oct. 8	43.99	9.49	77.65	3.98	2.41	.82	9.92

Spitzer, George, Carr, R. H., and Epple, W. F.- Soft corn - Its chemical composition and nitrogen distribution. Jour. Am. Chem. Soc. 41: 1212-1221. 1919.

"The percentages of normal starch and nitrogen free extract appear to be higher in soft than in mature corn. The formation of protein and carbohydrates apparently go on uninterruptedly during the growth of corn, while the fat seems to be formed last. The total nitrogen of soft corn is only slightly lower than that of mature corn, but the amide nitrogen is much higher. *** Since zein appears to be present in smaller amount in soft than in mature corn, and since glutelin, globulins, albumens, et cetera, are present to about the same percent in both mature and soft, it would seem that zein is formed last, and amide is formed at the expense of zein."

Wilson, J. W. and Bushey, Alfred L.- Soft corn for fattening cattle. S. Dak. Bul. 219. 1926.

The four lots of corn used in the feeding experiment were:

Lot I. Field run corn which had been snapped.

Lot II. Field run corn of the same variety as I.

Lot III. Selected "soft" corn from field run corn grown on the college farm.

Lot IV. Selected "hard" corn from the college grown corn. This lot was probably representative of the most mature corn which could be secured from this community.

Portions of the analyses of these samples as taken from the bulletin are shown in the following table:

Analysis of grain, cobs, and husks of four lots of corn used in experiment (In percent-water free basis)

Lot no.	Moisture	Protein	Ash	Ether extract	Sugar	Starch via diastase
Grain						
Lot I	21.1	12.77	1.81	3.33	1.98	55.8
Lot II	25.7	12.71	1.80	3.18	2.19	54.8
Lot III	28.1	12.66	1.67	2.73	1.68	54.1
Lot IV	20.9	11.10	1.54	4.06	1.93	56.0
Cobs						
Lot I	28.99	2.82	1.45	.454	2.72	
Lot II	28.51	2.72	1.81	.378	2.12	
Lot III	38.65	2.66	1.67	.253	2.67	
Lot IV	21.65	2.37	1.45	.326	2.85	
Husks from Lot I	8.72	3.32	2.66	.738	7.72	

These data are further broken down into classes of grain, and the composition by classes is shown in other tables in the bulletin.

For the feeding results of this experiment see p. 7.

Zeleny, Lawrence.- The distribution of nitrogen in the seed of Zea Mays at different stages of maturity. Cer. Chem. Vol. 12, No. 5, pp. 536-543. 1935.

"The globulin and glutelin of the corn kernel appear to be synthesized at a relatively uniform rate throughout the growth period. Zein is nearly absent in the very immature corn kernel but is synthesized at a very rapid rate as the corn approaches maturity. The asparagine, glutamine, or other amide content of the nonprotein nitrogen fraction remains relatively constant throughout the growth period of the corn kernel. The simpler amino compounds undergo rapid condensation as the corn approaches maturity. The basic nitrogen of the water-soluble nonprotein nitrogen fraction increases as the corn approaches maturity. At the same time the basic amino nitrogen falls to a very low value indicating that the water-soluble basic nitrogen compounds in mature corn consist chiefly of organic nitrogenous bases which do not yield primary alphatic amino compounds on hydrolysis."

Handling and Utilization

Evvard, John M.- The soft corn problem. Ia. Agr. Exp. Sta. Cir. No. 40. 1917.

"To classify soft corn simply upon the amounts of moisture present, the following approximate grading on that basis may be followed:

Percent moisture	Grade
65%	Markedly soft (rare).
55%	Very soft (somewhat difficult to squeeze out visible moisture).
45%	Soft.
35%	Fairly soft.
25%	Cribable.
20%	Safe corn.
14%	Old corn, mature.
12%	Usually two-year-old corn.
8%	Usually kiln-dried.

"Handling the soft corn crop successfully is somewhat of a perplexing problem, but there are a number of methods that suit different conditions, such as (1) ensiling, (2) shocking, (3) cribbing, (4) shredding, (5) marketing, and (6) feeding."

The author elaborates on each of these methods and the following are pertinent excerpts:

(1) Ensiling.- "The silo is the most acceptable place for storage for soft corn. The silage should be wet enough to run from 60 to 70 percent water when taken from the silo. *** Soft corn which has been frozen, but not spoiled, will make good silage. *** If corn is moldy it will not ensile well, but slightly moldy corn will be all right."

(2) Shocking.- "Shocking the corn, especially placing it in small shocks, will help to save the fodder (the stover) which is of high quality in a soft corn year. It will be of further advantage in that the ears will dry out quite rapidly, this being true in favorable seasons, when rains are not abundant."

(3) Cribbing.- "Cribbing the corn is the only means of storage that some farmers have. It is well, however, to leave the corn in the fields as long as possible, the ears hanging in their natural position from the stalks, where they dry better. Usually corn is safe to crib when it runs from 25 to 30 percent moisture."

(4) Shredding.- "Shredding soft corn is usually unsatisfactory; it is hard to shred, and if not well dried out it will spoil in storage."

(5) Marketing.- "In marketing soft corn, it is well to shell in the frozen condition and haul to market in the frozen state."

(6) Feeding.- "The feeding of soft corn is the most logical method of disposition. In general, however, there are two very essential precautions, which are best mentioned at the outset: Early feeding of soft corn, while its quality is still good, is in order; and feed often--three, four, and more times per day. Moldy feed is dangerous for horses particularly, and young sheep. Cattle are usually quite immune. Hogs can be trusted to eat what they will usually."

Hughes, H. D., Shedd, C. K., and Beresford, Rex.- We have some soft corn. Farm Science Reporter, Vol. 5, No. 4, pp. 3-5. October 1944.

Precautions should be taken in cribbing soft corn. Special ventilators or forced air drying are recommended. Feeding the soft corn is also recommended.

Nevens, W. B.- Silage crops for dairy cattle. Illinois Cir. 463. November 1936.

Soft ear corn may be ensiled for feeding. Tests on fattening cattle with this ensilage were satisfactory. But ear-corn silage is not ordinarily recommended as a feed for dairy cattle.

Richey, Frederick D.- Handling the soft corn crop. U. S. Dept. Agr. Dept. Cir. 333. 1924.

"Feeding offers the only hope of utilizing corn that is too immature to make marketable grain. Accustom your stock to soft corn as soon as possible, and begin feeding the least mature of it either by pasturing it or by cutting and feeding it. Part of it can be carried over for later feeding either as silage or fodder. Corn that is cut and shocked before the leaves drop off can be used to refill silos after the first filling has settled. In general, use the most immature corn for silage and that which is somewhat more mature for fodder.

"Use the nearly mature and slightly immature fields for grain. If the stover is needed also, cut the corn before the leaves are

lost. After it is in the shock it is reasonably safe until spring. If the stover is not needed, let the corn stay in the field awhile. The ears will dry out a good deal in 30 days.

"Do not crib the nearly mature and immature corn together. Sort the ears before cribbing. Nearly mature ears will make fair grain if properly handled, but frequently will mold or rot if stored with very wet immature ears.

"In cribbing soft corn, remember that the most important thing is ventilation. If the corn is nearly mature, sorting and thorough ventilation may be all that is needed to save it. Do not pile it up in one crib. Scatter it as much as possible. If you think this is not enough, use salt--8 to 12 quarts to the load of corn. Salt will not dry the corn, but it will help to draw out the moisture and check the development of mold. Plenty of ventilation will do the rest.

"Keep in mind the possibilities of artificial drying. This may be the best method of handling slightly immature corn when the stover is not needed. It is expensive, though, and the use of salt with thorough ventilation may be just as efficient under many conditions.

"It makes little difference what kind of ventilators are used if you use enough of them. The only way to get the water out of soft corn is to let it evaporate. It can not do this unless moving air can get to every part of the crib."

Robison, W. L.- Palatability and feeding value of different corns for pigs. Ohio Agr. Expt. Sta. Bimo. Bul. Vol. 29, pp. 188-206. 1944.

"Immature corn, that was kept from molding by drying, was worth fully as much per pound of dry matter contained, as was mature corn. The loss from late planted or immature corn, that is kept without spoiling, is in a reduced yield of grain, on a dry matter basis, per acre rather than in a lowered feeding value, per pound of dry matter produced.

"Freezing did not impair the nutritive value of immature corn."

Shedd, C. K.- Handling and storing soft corn on the farm. U. S. Dept. Agr. Farmers' Bul. No. 1976. 1945.

Experience indicates the following as some of the means of reducing damage to corn in crib storage.

"Delay harvesting--the corn will become drier late in the season, and the lower temperatures will retard or prevent winter growth of mold in the crib. Some farmers delayed harvesting the 1944 crop until the following spring with good results. ***

"Sort the corn, taking out the green or soft ears for immediate feeding.

"Provide ample ventilators to give the wind access to the corn in the crib." ***

Designs of cribs and ventilators are given with specifications for material needed for construction.

U. S. Department of Agriculture.- Suggestions for handling soft corn. Weekly News Letter, January 23, 1918.

This news letter was issued after the soft, immature and frosted corn crop was experienced in 1917. The suggestions are for storing the corn in well ventilated cribs, and for marketing frozen corn. Attention is called to the fact that shrinkage in dried corn is considerably greater than the difference in the moisture content before and after drying. It is also pointed out that salting ear corn will retard heating.

University of Illinois.- Soft corn, how to store and feed it. Ill. Cir. No. 293. 1924; Supplement, September 1935.

The storing of soft corn in pit silo and in cribs is discussed, with directions given for their construction.

"Feeding trials in Iowa indicate the advisability of using more protein supplements with soft corn than is necessary for best results with mature corn."

University of Illinois.- Temporary or emergency silos. Ext. Service of University of Illinois. September 1943.

Directions are given for building above ground fence and paper silos and trench silos.

Wilson, J. W. and Bushey, Alfred L.- Soft corn for fattening cattle.- South Dakota Bul. 219. 1926.

"The results of this experiment indicate that farmers should plan to feed soft or immature corn rather than sell it on the market, because when fed with alfalfa hay soft corn produced gains which compare favorably with gains produced by the more mature corn grown the same year.

"The results also indicate that husks on the immature corn have considerable feeding value; steers fed snapped corn and alfalfa hay made better gains than steers fed husked corn from the same field.

"Results indicate that soft corn puts a good finish on cattle as the salesmen in the stockyards rated the steers that received the soft selected corn second, and the steers that received the hard selected fourth. ***

"From the records of the Lots III and IV (Lot III was fed soft selected ear corn and alfalfa hay; and IV, fed hard selected ear corn and alfalfa hay), it is evident that .52 of a pound more of the soft selected corn was required to produce a pound of gain than was required in Lot IV where the hard selected corn was fed. The average daily ration per head for steers that received soft selected corn was larger than for steers that received hard selected corn but the difference is not sufficient to justify the difference in prices paid for soft corn and matured corn for feeding. The pigs in the soft corn lot did not make as good a return for a bushel of corn fed as pigs did in the lot that received the hard selected corn." (See also p. 3.)

Drying

Anonymous.- Easy way to dry soft corn. Wallaces' Farmer, p. 12, September 1, 1945.

This article stresses the fact that hybrid corn will stand all winter and still have the ears off the ground on the spring. With this change in the corn itself, the best policy is to leave the corn in the field until it is dry enough to crib.

Use of Preservatives

Hughes, H. D.- Salting soft corn. Iowa Agr. Exp. Sta. Cir. No. 41. 1917.

"It would appear that salt is of considerable value in retarding fermentation and the development of molds in soft corn, and that in cribbing soft corn from 1/2 to 1 pound of salt per 100 pounds of soft corn may be used to advantage, the amount depending somewhat upon the condition of the corn. While 2 pounds of salt per 100 pounds of corn appears to give noticeably better results than 1 pound, it is probable that this amount of salt cannot be used safely when the corn is to be fed to livestock." ***

It is necessary, however, that care be taken to provide the best ventilation in the cribbing or the use of salt will not prevent the development of molds or of heating.

Richey, Frederick D.- Handling the soft corn crop. U. S. Dept. Agr. Dept. Cir. 333. 1924.

"Salting as a means of preserving soft corn came into prominence in the fall of 1917. Experiments by the Iowa and Illinois Agricultural Experiment Stations and observations of cribs of salted corn indicate that this method can be used to good advantage in connection with thorough ventilation.

"Salting corn is not a cure-all. There is no way to keep corn sweet without getting the water out of it. Salt will tend to draw out the moisture, check the development of mold, and help to prevent heating in the crib. Then ample ventilation will dry out the corn so rapidly that a good quality will result. It is better to spread the corn uniformly in the crib and sprinkle the salt over this evenly. The standard recommendation is 8 quarts of salt for a 40-bushel load of corn. This may be increased to 12 quarts if the corn is very soft."

U. S. Department of Agriculture.- Suggestions for handling soft corn. Weekly News Letter, January 23, 1918.

Contains a reference on salting soft corn. For details, see same reference under preceding heading.

University of Illinois.- Handling, storing, and feeding soft corn. Extension Service of University of Illinois. September 1943.

Soft corn may contain moisture in the ears to the extent of from 26 to 65 percent of the total weight of the ears.

Four methods of handling soft corn are: (1) Make into silage; (2) leave on standing stalk in field; (3) cut and shock; (4) husk and crib.

From an extensive study of the feeding value of ear-corn silage, it was concluded that the best way of salvaging a soft corn crop is to put the entire crop into the silo immediately after it freezes. It was also proved that ear-corn silage did not prove to be a good feed for fattening hogs, and that cattle do not gain so rapidly as on a full feed of sound corn.

PART II. OTHER CORN

Drying

Adams, S. L., Stark, W. H., Kolachov, Paul.- Reduction of the fermentable carbohydrate content of corn by kiln drying. Cer. Chem. Vol. 20, No. 2, pp. 260-266. 1943.

In order to determine the effect of kiln drying on the fermentable carbohydrate content of corn, a number of samples were obtained from an experimental commercial drier dried at various temperatures for varying lengths of time. Results of these investigations showed that there is a decrease in yield of 0.1 to 0.2 proof gallon per bushel from all kiln-dried corn. This effect appears to be relatively independent of reduction of the length of exposure to the drying temperature. It appears that the action of the heat on the starch produces a certain amount of unfermentable dextrins. That the change is due to heat and not to dehydration of the kernel has been proved by fermentation tests on corn dried at room temperature. The effect of kiln drying varies with the type of equipment used. Tables are given showing alcohol yields from the corn dried by the various driers.

"Kiln drying of corn results in a 2 to 3 percent decrease in alcohol yield. Under certain conditions, kiln drying of corn at temperatures of 200° F. and above may result in a decrease of 4 to 6 percent in the alcohol yield.

"Since the effect of kiln drying varies with the type of equipment used it should be advantageous to the grain companies and to the manufacturers of kiln-drying equipment to institute a thorough program of research on the problem. The most feasible plan would be to conduct fermentation studies on corn dried in laboratory-scale models of the various types of commercial driers.

"The action of heat on the fermentable carbohydrate portion of the grain has not been definitely characterized but is probably a formation of a certain amount of unfermentable dextrins."

Bartling, F. W.- Wet-process corn milling. No. 4C - Receiving, weighing, cleaning, storing. American Miller, Vol. 68, No. 6, pp. 44-45. 1940.

"Corn drying plants have been installed by some of the larger grinders for reducing the moisture content of corn considered too wet for storage and for removing sour and moldy odors."

A diagrammatic picture is shown of the drying plant.

"Artificially dried corn is rendered brittle and tends to break up when turned over the cleaner and other machinery. The loss in weight due to drying always exceeds the reduction in the percentage of moisture and is additional to the usual shrinkage experienced when running it over the channels of the work house."

A shipment of wet corn possessing a high degree of 60 cc. acidity, indicating that it was deteriorating and would become a storage hazard, was dried. It was estimated that the cost of drying came to about 1/2 cent per bushel.

Cox, Mary J., MacMasters, M. M., and Hilbert, G. E.- Effect of the sulfurous acid steep in corn wet milling. Cer. Chem., Vol. 21, No. 6, pp. 447 to 465. 1944.

"It is common knowledge among corn wet millers that great difficulty is experienced in processing corn artificially dried at 180° to 200° F., apparently because of changes brought about in the endosperm. A sample of corn dried under these conditions was steeped in a 0.2 percent sulfur dioxide solution for 24 hours at 49° C. The strands in the protein network appeared slightly narrower in the dried corn and upon steeping did not swell to the same extent as those in corn artificially dried. The starch was, moreover, held more tenaciously by the protein matrix in the artificially dried sample. Protein dispersal during steeping appeared to be nearly normal, except that the disintegrating matrix left pieces which adhered closely to the starch granules. Upon extraction it was impossible to separate all of the gluten from the starch and a prime-quality starch was not obtained."

"A second sample of corn, artificially dried at 120° F., appeared intermediate in behavior between corn dried in the field and that dried at 180° to 200° F."

Henderson, S. M.- Resistance of shelled corn and bin walls to air flow. Agric. Engineering 24 (11), 367-9, 374. 1943. Biol. abs. 18, 225-33. 1944.

A full description is given of the method of procedure and apparatus used.

Through a depth of 4 feet of shelled corn the rate of flow for a pressure of 1 inch of water was 24 c.f.m. per square foot of a column of corn, the corn being clean and the floor resistance to air flow negligible. With 3 percent of cracked corn and foreign material the equivalent depth of clean corn was 20 percent greater or 4.8 feet. The flow for a pressure of 1 inch of water for this depth was 22 c.f.m., a reduction of 2 c.f.m. Floor openings of 2 percent produced a resistance equivalent to 2.5 feet of clean corn. The flow for the 4-foot column of corn for 1-inch water pressure was 17 c.f.m. per square foot. A 4-foot column of corn containing 3 percent of cracked kernels and other debris produced a total equivalent depthof 7.3 feet, or a flow for 1-inch water pressure of 15.5 c.f.m. It is estimated that a maximum reduction of about 15 percent in flow through 8 feet of shelled corn was produced by tamping.

The size and shape of kernels affect resistance to air flow. Corn weighing only 24.4 g. per 100 kernels permitted only 93 percent as much air to pass as did larger kernels weighing 32.0 g. per 100. Rectangular to round kernels were more resistant to air flow than smaller round kernels. Also, blends of these are more resistant than unmixed corn.

Hume, Albert N. and Center, O. D.- The shrinkage of ear corn in cribs. Ill. Bul. 113. 1907.

Starting in December with ear corn that was reasonably mature and sound, weighings of it were made when cribbed and at intervals of three months over a period of two years. It was found that by far the most noticeable shrinkage occurred during the months of April and May, and that by the end of one year, moisture content had become stabilized with no further loss of weight.

Price, F. E. and Branton, Ivan.- Corn drying. Oregon State Bul. 352. 1937.

Full information is given on drying both shelled and ear corn. Costs and methods, including diagrams and construction details, are given.

The amount of heat required to dry one ton of shelled corn from 30 percent moisture to 12 percent in a continuous-process drier was found to be approximately 1,334,000 B.t.u.

A 500-pound per hour shelled-corn drier operating near Corvallis required approximately 1 cord of wood to turn out 7 tons of shelled corn at 12 percent moisture from an initial 30 percent moisture. This would amount to 60 cents per ton of dry shelled corn with Douglas Fir wood at $4.00 per cord.

The ear-corn driers, natural-draft, and forced-draft are described. Rates of drying at temperatures ranging from 120° F. to 200° F. are given.

Staub, S.- Description of a maize dryer at Ferney, S. E. Rev. Agric. Ile Maurice 22 (5): 210-211. 1943. Biol. abstract Vol. 19: 5175. 1945.

"The maize dryer, designed on the barn principle, is enclosed in a masonry room 19 x 15 feet x 27 feet high, covered with a metal roof. Heat energy is produced exclusively by burning maize cobs. The maize is shelled, deposited in a bin, and dried by hot air forced through the perforated bottom of the bin. Air is heated by contact with metal surfaces, that are in turn heated by hot gases from the furnaces. Three sections of the dryer are shown."

Physical and Chemical Changes During Storage

Bailey, C. H.- Respiration of shelled corn. Minn. Tech. Bul. 3. 1921.

"During the curing of husked ear corn the percentage of moisture is appreciably higher in the cob than in the grain during the early stages, but the cob loses moisture at a more rapid rate than the kernels, and as the cob approaches dryness (9 percent of moisture) the kernels contain more moisture than the cob.

*** "During the curing of corn on the cob immediately after harvest, the rate of respiration is lower for a time than that of corn of the same moisture content later in the season. Possibly a form of dormancy is involved, resulting from a reduced rate of diffusion of oxygen into the respiring cells, or of CO_2 therefrom, or both. This condition is of significance in that the probability of heating is diminished during the period immediately after harvest when the moisture content of the grain is usually high.

"Cracked and broken kernels respire more vigorously than sound corn.....

"Temperature affects the rate of respiration, an increase of 10 degrees, from 27.8° to 37.8° C., nearly doubling the rate throughout the range of moisture studied."

Barre, H. J. and Kelly, C. F.- Grain storage problems and investigations. U. S. Dept. Agr. publication, ACE 127. 1941.

Ear corn storage investigations showed that corn placed in cribs in the fall of 1940 contained moisture in excess of 25 percent. An unusual amount was moldy by the following spring. Types of cribs are described.

The storage of dry shelled corn is successful when the moisture content is not greater than 13 percent.

Storage studies were made on other grains.

Besley, H. J. and Baston, G. H.- Acidity as a factor in determining the degree of soundness in corn. U. S. Dept. Agr. Bul. No. 102. 1914.

"The degree of acidity of corn should not necessarily be considered a measure of the percentage of individual kernels that are visibly damaged. It is the soundness and quality of the corn which is indicated by the acidity test, and the results of this investigation suggest the acidity test as a method to be used in determining accurately the soundness and quality of corn."

A number of tables are presented indicating relationships between acidity and germination, temperature, destination of corn, et cetera.

Boerner, E. G.- Factors influencing the carrying qualities of American export corn. U. S. Dept. Agr. Bul. 764. 1919.

"Thoroughly air-dried corn contains from about 12 to 13 percent of moisture. Such corn may be shipped for export at any time under ordinary conditions with little or no danger from heating in transit, and this is practically true also of corn containing up to 14 percent moisture provided fermentation has not started. The fact that certain lots of corn contain higher percentages of moisture does not necessarily mean that they will not stand ocean shipment safely." ***

"When corn 'goes out of condition' the effect of its relative moisture content immediately becomes evident. Corn with a low moisture content requires a much longer time to reach that stage designated as 'hot' or to become discolored or 'damaged' by the process of heating, than corn with a high moisture content, while corn with a high moisture content will heat, become discolored,

and lose weight by evaporation quickly, and the processes of deterioration are accelerated with each additional percent of moisture much more rapidly than the proportionate increase in the moisture content. When corn of a low moisture content is found in a heating condition, it can ordinarily be restored to a cool condition with but a slight amount of handling and ventilating and without much, if any, loss in value through discoloration, while corn with a high moisture content, when heated in any considerable bulk, quickly becomes badly discolored and damaged and is restored to a cool condition with great difficulty and a great amount of handling only with more or less damage to its quality and a corresponding loss in value."

Culbertson, C. C.- Debunk fear of old corn. Wallaces' Farmer and Iowa Homestead. Vol. 67, No. 14, p. 11. July 11, 1942.

C. C. Culbertson, of the Iowa Agricultural Experiment Station, stated that throughout Iowa during the year there had been cases of edema et cetera, apparently caused by feeding vitamin-poor old corn, but that in most of the edema cases the steers had been getting both old hay and old corn. If good legume hay is fed along with old corn, there should be no such trouble. In this year's experiment results showed that there was less difference than was at first indicated in the feeding of old corn compared to new, both with the corn fed shelled and in combination with alfalfa hay. As a matter of fact, it was found that some 1937 corn did a little better than the 1940 corn because the latter--although three years younger--had dried to a harder condition.

Doty, D. M., Smith, Glenn M., Roach, J. R., and Sullivan, J. T.- The effect of storage on the chemical composition of some inbred and hybrid strains of sweet corn. Purdue Bul. 503. 1945.

Thirty-nine inbred and hybrid strains of sweet corn were studied during the seasons from 1935 to 1938. These were harvested when considered in prime condition for canning at about 70 percent moisture content.

"Polysaccharides increased while sucrose and reducing sugars decreased in all strains of green sweet corn stored at 68° F. The rate of this change of sugars to polysaccharides was usually more rapid during the early part of the storage period.

"The rate of sugar loss during storage for each strain of sweet corn was similar from year to year, which indicates that the internal factors affecting the change from sugars to polysaccharides during storage of sweet corn are controlled in part by the genetic constitution of the plant."

Duvel, J. W. T.- The deterioration of corn in storage. U. S. Dept. Agr. Circ. No. 43. 1909.

Five thousand five hundred and fifty bushels of sound shelled corn varying in moisture content from 17.0 to 18.8 percent were put in storage February 17 and 18 at Baltimore. On March 26 this corn showed signs of deterioration by a sour odor at the top of the bin. Later a rise in temperature was noted, 133° F. on April 27. At the end of the experiment, the moisture content of the corn immediately at the surface was 14.95 percent, or 3.35 percent less than on February 17. The moisture content of the 1,000 bushels at the top of the bin exclusive of the corn on the surface, was slightly higher than when the corn was placed in the bin, showing that the deterioration of the corn was resulting in the formation of more water than was being given off by evaporation. Weight shrinkage from 69 days storage was less than one-tenth of one percent.

Franke, Erich--head of the production laboratory of the Fleischmann Yeast Company at Pekin, Illinois.- Observations, based on 15 years' experience in fermentation industries in Czechoslovakia and this country, on characteristics of stored grains.

Rye and corn begin to show a resistance to malt saccharification some 8 or 9 months after harvesting. This resistance remains essentially the same from then on. Treatment with malt diastase for a longer time will increase the saccharification to the original value. Addition of more enzyme will help to a certain extent, but will not bring saccharification to the original rate. These observations have been repeated year after year and it is evident that they are not due to seasonable variations. Experiments have shown that neither the moisture nor the nitrogen content of the grain changes. Change in strength of the malt diastase was investigated but showed no difference, indicating the difference to be in the grain itself.

It was further noted that during saccharification, starch from fresh grain stained first blue, then violet, then red, and finally was colorless with iodine, while the old grain went from blue to colorless without going through the other colors.

In connection with the storage of potatoes for use by distilleries in the production of alcohol, it was found that the piping of carbon dioxide from the distillery to the storage bins prolonged the satisfactory storage period of the potatoes. This obviously slows down respiration and delays enzymic changes.

Geddes, W. F.- Discussion before a meeting of the Minneapolis chapter, Society of Grain Elevator Supt's. Minneapolis, October 27, 1942. Feedstuffs, Vol. 14, No. 45, p. 14. November 7, 1942.

*** "Regardless of the effects of various mold growths on grain heating, the grain respiration process is a common cause of damage. By studies of the carbon dioxide produced, curves have been drawn to indicate safe moisture limits for various types of grain in

storage when other things are equal. The 'break' in the curve, that is, the danger point, is reached more rapidly for some grains than others, the oil content being a major factor in this. Flax, for example, has the earliest break, rye the latest. Corn curves indicated that at 11 percent moisture virtually no carbon dioxide (or respiratory heat) was produced. At 12 percent a small amount is evolved, and at 14 percent a much larger amount was obtained over a given period. The break occurs there--above 14 percent heating mounts rapidly. Cereal grains were fairly well grouped, corn being slightly quicker to heat than others. The tests were conducted at a relatively high initial temperature."

Dr. Geddes explained that since oil was not miscible, the moisture content of non-oil portions of grains was higher than would be indicated by grain weight, thus accounting for the more rapid heating of grains higher in oil.

Work on soybeans was begun only last year. Because of its oil content, its heating curve falls between corn and flaxseed.

James, L. H., Rettger, L. F., and Thom, C.- Microbial thermogenesis. II. Heat production in moist organic materials with special reference to the part played by microorganisms. Jour. Bact. Vol. 15, pp. 117-141. 1928.

"Moistened cornmeal and cracked corn heated to 62.+° C. in a specially designed apparatus, when aerated with oxygen. Moistened wheat and oats heated to a less extent under the same conditions.

"Bacteriological examination of meal at various stages of the rise in temperature showed an increase in the numbers of organisms growing at 30° C. to a point when the temperature had reached 50° C. beyond that a marked decrease occurred."

Jones, D. Breese, Divine, J. P., and Gersdorff, Chas. E. F.- The effect of storage of corn on the chemical properties of its protein and on its growth-promoting value. Cer. Chem. 19: 819-830. 1943.

"The effects of storage of ground corn and of whole shelled corn upon the properties of the proteins and upon nutritive value were determined at various intervals over a storage period of two years. The results show that three different types of alterations in the proteins occur: (1) A decrease in the solubility of the proteins, (2) a partial breakdown of the proteins, indicated by a decrease in true protein content, and (3) a decrease in digestibility.

"The extent of the alterations is influenced by temperature, type of container, duration of storage, and the nature of the material stored. Samples stored at 76° F. were affected more than those at 30° F., and those in bags more than those in sealed glass jars. Changes in the ground corn were greater than those in the whole shelled corn. *** Rates of decreases in protein were much more rapid during the early storage intervals. *** Significant decreases in feeding value were found." The digestibility was reduced progressively up to a year's storage and there was no change from the end of the first year to the end of the second year.

Leavitt, Sherman, and Le Clerc, J. A.- Change in the composition of unground cereals during storage. Jour. Ind. and Eng. Chem. Vol. 1, pp. 299-302. 1909.

The authors found notable decreases in the percentage of sugar in corn which was stored for 2 years; barley and oats showed small decreases while wheat and rye changed slightly. Some samples of wheat showed an actual increase in sugar content. The other constituents changed very little or not at all.

McHargue, J. S.- The cause of deterioration and spoiling of corn and cornmeal. Jour. Ind. Eng. Chem. Vol. 12, No. 3, pp. 258-262. 1920.

Conclusions:

"1. Excessive moisture is the chief cause of the deterioration and spoiling of corn.

2. Sound grains of corn containing not more than 12 percent of moisture can be preserved for a considerable length of time.

3. Grains of corn containing 12 percent of moisture will readily absorb more when exposed to conditions in which free moisture is present.

4. Molds will develop on grains of corn containing as much as 15 percent of moisture at normal temperatures and with restricted ventilation.

5. Molds cause a very rapid deterioration of the oil, sugar, and starch contained in the germs of corn.

6. Alcoholic and acetic acid fermentations take place when grains of corn containing more than 20 percent of moisture are deprived of ventilation and kept at normal temperatures.

7. Apparently the cause of export corn spoiling is that it is not thoroughly air dry (12 percent moisture) before being put into the dry holds and is not kept at that state of dryness during the voyage.

8. The germ contained in sound grains of corn apparently contains an easily oxidizable substance and when fresh meal is made from whole grains of corn and exposed to the atmosphere the acidity increases as a result of the absorption of oxygen from the air.

9. Meal made from whole grains of sound corn containing 12 percent moisture can be kept in a condition suitable for human consumption from 4 to 6 months provided moisture and air are excluded.

10. Cornmeal deprived of its moisture undergoes little or no change in acidity.

11. Lowering of temperatures retards the development of acidity in cornmeal.

12. Meal made from degerminated grains of corn is inferior to meal made from whole grains of corn."

Malhotra, R. C.- Chemistry of corn seed germination. Cereal Chem. 11, 105-9. 1934.

"Starch, hemicelluloses, calories of heat, as well as fats, decreased while sugars increased during corn seed germination. Proteins remained constant. Seedling weighed less than seed. Embryo contributed fats, and endosperm supplied carbohydrates during germination. When corn isolated embryo was allowed to germinate, fats, starch, hemicelluloses, sugar, and calories of heat decreased. Nitrogen and ash did not change. Chemical substances did not change in germinating embryoless endosperm, although starch was reduced to sugar by auto-digestion."

Sayre, J. D.- Storage tests with seed corn. Ohio Jour. Sci. Vol. 40, pp. 181-5. 1940; Exp. Sta. Rec. Vol. 85, p. 341. 1941.

"Kernels of Clarage corn, sealed in glass tubes and containing 18 percent moisture, remained viable after 6 years when stored at temperatures below freezing but died in less than 6 months at room temperature (about 30° C.). When stored at about 30° C. kernels stored in oxygen died in 3 years and in nitrogen or carbon dioxide decreased noticeably in germination, whereas those stored at low temperatures in these gases or air gave good germination after 5 years."

Slusanschi, Horia.- The changes in the chemical character of grains during storage. Analele Inst. Cercetari Agron. Romanici 11, 320-26. 1939. Chem. Zentr. 1941, I, 2051. C.A. 37, 4481[9]. 1943.

"The changes in the acidity and pH of both ground and unground samples of corn (probably means wheat) during storage were determined. Increases in acidity and pH are an indication of vigorous chemical decomposition--processes mostly of a fermentative nature. These processes were accelerated by the presence of 13 percent moisture and by fat substances in higher concentration. This is particularly true of the stored ground grain."

Wallaces' Farmer and Iowa Homestead.- Don't give steers old feed. p. 3. April 18, 1942.

"Feeding beef steers exclusively on hay and corn that are several years old is now regarded as an unwise practice. Such feeds may have depreciated so much in vitamin content that the animals will develop edema, or swelling of the legs and quarters. Such affected animals may be condemned when shipped to market, and often some will die in the feed-lot." .....

The Illinois Experiment Station also reports that beef cattle fed on three and four-year-old corn thrive well for some time, until their front legs begin to swell. Lameness, loss of appetite and rapid loss of flesh are other symptoms.

Chemical analysis of old yellow corn by Illinois Experiment Station workers has shown Vitamin A content only half as great as in new corn.

Zeleny, Lawrence, and Coleman, D. A.- The chemical determination of soundness in corn. U. S. Dept. Agr. Tech. Bul. 644. 1939.

"As deterioration of the corn kernel is necessarily associated with chemical changes in several of its components, the more important of these chemical changes have been studied in an effort to discover some easily measurable change that will serve as a reasonably accurate index of the degree of deterioration. It has been shown that the quantity of free fatty acids, amino acids, and acid phosphates in the kernel, tend to increase as deterioration progresses.

"Of these three types of acidity only the fat acidity increases significantly with incipient deterioration and is therefore the only type of acidity which appears to be useful in differentiating degrees of soundness in corn."

Zeleny, Lawrence.- Fat acidity in relation to heating of corn in storage. Cer. Chem. 17: 29-37. 1940. C.A. 34: 2090. 1940.

"The rate at which heat is developed depends upon the moisture content of the grain, the temperature, the available O_2 supply, and upon certain characteristics of the grain itself, which are not completely understood. The acidity of grain, particularly of corn is a more reliable measure of its degree of soundness than other available chemical or physical tests. Fat acidity is expressed in terms of mg. of KOH required to neutralize the free fatty acids extracted from 100 g. of corn calculated to a dry matter basis. The rate of spontaneous heating of grain can be predicted much more accurately when moisture and fat acidity are considered together than with moisture alone. It was shown that corn with a moisture content of 17 percent and a fat acidity of 100 can be expected to heat in storage as rapidly as corn with a moisture content of 21 percent and a fat acidity value of 20."

PART III. OTHER GRAIN OR SEEDS

Drying

Birchard, F. J.- Drying of wheat. Can. Dept. Trade and Commerce, Dom. Grain Res. Lab., 6th Ann. Rept. 1932, 20-1. 1933. C.A. 28: 3800. 1934.

"No injury to the grain or to the baking qualities of the flour was produced by drying wheat at temperatures up to 180° F. for 40 min. Drying at 200° F. caused a decrease in the protein content of the grain, the H_2O absorption of the flour, and the loaf volume and texture of the bread; the color was inferior and the general baking quality was good to fair."

Camilla, Stefano.- Artificial drying of grains is necessary for their storage and use in panification. Atti I congr. intern. panificazione Roma 1932, p. 272-80. 1933. C.A. 28: 1780. 1934.

"The artificial drying of wheat gives practically the same quality of flour as that produced from wheat dried normally for 1 month. The wheat was analyzed for H_2O and 80 percent soluble and insoluble protein. The flour was analyzed for H_2O, gluten, gliadin, and glutenin."

Cox, J. H.- The drying for milling purposes of damp and garlicky wheat. U. S. Dept. Agr. Bul. No. 455. 1916.

"The results of these investigations show practically no bad effects from the drying of wheat at 140° F. and indicate that this temperature is probably the most satisfactory for the drying of wheat, either with or without garlic, for milling purposes."

Engler, Kyle and McNeal, Xzin.- Artificial drying of combined rice. Agric. Engineering 25 (10): 379-380. Biol. Abs. Vol. 19: 5156. 1945.

"The experimental results indicated that commercial practices are well within the safe drying ranges and also that higher drying temperatures and increased drying rates will prove satisfactory. Rice dried more readily when it was stored and permitted to heat slightly. However, it has not been determined how high the temperature may go or the duration of abnormal temperatures before milling quality is reduced or germination is destroyed."

Fisher, E. A. and Hines, S. F.- Observations on the rate of movement of water in wheat. Cer. Chem. 16: 584-598. 1939.

"When a colloidal material, such as wool, cotton, gelatin, or wheat, and water are mixed and allowed to stand at constant temperature a progressive shrinkage of the mixture occurs.***

"An attempt has been made, by a simple but accurate method, to measure these volume changes over periods of days in mixtures of wheat and water. The rates of such volume changes should be related to the rates of movement of water throughout the wheat, to the original moisture content of the wheat, and to other factors. The results obtained, although of considerable interest, are anomalous and can only be interpreted as indicating the presence of fine cracks or fissures in the wheat, or the production of fine cracks or an increase in size of pre-existing cracks during the moistening. Such cracks make it impossible to measure the real shrinkage that undoubtedly occurs. ***"

Fisher, E. A. and Jones, C. R.- A note on moisture interchange in mixed wheats, with observations on the rate of absorption of moisture by wheat. Cer. Chem. 16: 573-583. 1939.

"The evidence suggests that the well-known difficulty of getting sufficient water into hard, dry wheats such as durums and Indians is due not to the hardness but to the dryness of the wheat. To

test this point the rate of absorption of water vapor from the air by durum and by English wheat was measured, and it was found that under strictly similar conditions of temperature, atmospheric humidity, and moisture content, durum wheat may absorb moisture at a rate 20 percent faster than soft and starch English wheat."

Gay, F. J.- A further study of temperature changes during the "turning" of bulk wheat. Australia Counc. Sci. and Indust. Res. Journal 14 (4), 245-248. 1941. Biol. Abs. 17: 16971. 1943.

"Temperature changes were recorded at about 11-second intervals during 2 turnings of 7,500 bushels of wheat from one bin to another in the winter. The temperature out of doors at the first turning was 18.3° C. The first turning took 3 hours; the second, which began 16 hours later, took 3-1/2 hours. During the first the temperature varied between 21° and 40° C. This is considered a marked cooling, 6.7° more than had been obtained by turning in summer."

Harris, Frank S. and Thomas, George.- The change in weight of grain in arid regions during storage. Utah Bul. 130. 1914.

In the arid region the grain weighed less at harvest than at any subsequent time. It gained moisture during the winter and dried out during following summer.

Henderson, S. Milton.- Resistance of soybeans and oats to air flow. Agric. Engineering 25, 127-8. 1944.

Studies were made and data presented to show resistance to air flow in clean grain, in settled grain, and in grain stored on perforated steel sheets. Also a comparison is given of the rate of air flow for shelled corn, oats, sorghum, soybeans, wheat, and barley, for depths ranging from 0.5 to 8.0 feet and air pressures ranging from 0.10 to 3.0 inches of water.

Hurst, W. M. and Humphries, W. R.- An absorptive agent for drying grain. Agr. Eng. 17, 62, 1936. C.A. 30: 4936. 1936.

"The moisture content of 500-gram samples of wheat, soybeans, flax, corn, and rice was increased to 20 percent by adding water and storing in airtight containers for approximately 48 hours. An inert SiO_2 product, the nature of which is not stated, was then thoroughly mixed with the grain in quantity ranging from 116 to 277.6 grams. Analyses of the grain, after it was separated from the SiO_2 showed 10.0-13.7 and 9.4-12.9 percent moisture after contact with the drying agent for 48 and 72 hours respectively. The greater portion of the moisture was absorbed in 24 hours. Samples left in contact with the drier for 72 hours usually showed a further reduction in moisture. With an initial moisture content of 18 percent, 1 bushel of wheat requires approximately 7.5 pounds of the drier to reduce the moisture content to 14 percent which is about the maximum limit for safe storage of wheat."

Rusca, Ralph A. and Gerdes, Francis L.- Effects of artificially drying seed cotton on certain quality elements of cottonseed in storage. U. S. Dept. Agr. Cir. No. 651, p. 16. July 1942.

"The conditions under which cottonseed is stored have an important bearing on the quality of the seed after prolonged periods of storage. Excessive moisture content and overheating of the seed not only have an ultimate adverse effect on the quality of oil extracted from stored seed but they may also influence its germinative properties" ...

"Results of the 2-year study, in which 23 cottons were used, have been compiled and analyzed. They indicate that with green, damp, or wet seed cottons, the process of artificially drying before ginning did not cause an increase in the rate of deterioration of the seed in storage; that in fact, it caused retardation of the formation of free fatty acids. The higher the drying temperature used, the less was the free fatty acid content of the seed at the end of the 90-day storage period."...

"Germination tests on the undried and dried seed indicate that a free fatty acid content of 2 percent becomes critical as far as cottonseed germination is concerned."

Smith, W. D. et al.- Artificial drying of rice on the farm. U. S. Dept. Agr. Cir. 292. 1933.

A drying air temperature of 120° F. can be used without injury to the rice if the moisture content is reduced only about 2 percent at each drying operation, and the rice is allowed to remain in storage from 12 to 14 hours between dryings.

Temperatures of 110, 120, 130, and 140° F., and rices of 25 to 27 percent moisture content were experimented with. These rices were dried to about 14 percent.

Stansfield, E. and Cook, W. H.- The drying of wheat. Dom. of Can. National Research Council. Rept. No. 24, 1929 and Rept. No. 25, 1932.

The summary and conclusions for the investigations in Report No. 24 are:

"(1) A marked deterioration occurred with wheat containing 15-17 percent moisture when heated for 3 hours at 212° F.

(2) Deterioration with wheat containing 16 percent moisture was first noticed at 185° F. This was very marked at 194° F. and more so at 203° F.

(3) No deterioration occurred in heating wheat containing 15.2 percent moisture until 203° F. was reached.

(4) Wheat containing 17 percent moisture was not injured until 194° F. was reached.

(5) In one experiment a slight deterioration was noticed with wheat containing 15.2 percent moisture when heated at 176° F."

The cause of the irregular variations cannot be explained from these experiments.

The second report continued and extended the work reported in the first bulletin.

"The temperature attained by the wheat was studied because of its probable connection with injury to baking quality. Drying to a low final moisture content tends to give high wheat temperatures, since the cooling effect of evaporation is reduced as the grain becomes drier. Rapid drying also gives high wheat temperatures. There is apparently little relation between the initial moisture content and the temperature attained by the wheat. These results show that over-drying and rapid-drying are the main causes of high grain temperatures in the heater section."

"The effect of various drying conditions on the subsequent milling and baking quality was determined by milling the samples.

"The milling results as shown in Report 24 indicate that there is no significant difference in the yield of flour under the tested conditions of drying, hence the milling quality was unaffected by drying. The baking quality on the other hand, showed injury under certain conditions.

"The condition upon which injury to baking quality is most dependent is the temperature of the hot air. The results obtained show, in agreement with the conclusions stated in Report 24, that 180° F. is maximum safe temperature for the drying air. Above this limit the extent of injury increases with the temperature and rate of air flow, that is, with the rate of drying. Even at 180° F. damage may occur, if high air flows are used. Injury from rapid drying is unlikely if the wheat remains in the heater section not less than 10 minutes for each 1 percent loss in weight when the wheat is dried over a moisture range of 19 to 14 percent.

"The extent of injury is apparently not dependent on the initial moisture content of the wheat. Grain of high or low moisture content can be dried with equal safety provided an air temperature of 180° F. is not exceeded, and the rate of drying is not excessive.

Whymper, R. and Bradley, A.- Studies on the vitality of wheat. II. Vitality, and the action of heat on wheat seeds. Cer. Chem. 11, 625-36. 1934.

Both longevity and germinative energy of wheat seeds are increased by drying at room temperature, while embryo is chemically and physically changed by drying at any temperature.

The limit of heat that can be applied to seeds without causing death depends upon the original moisture content of the seeds at the time of heating, the germinative energy of the seeds at that time, and the duration of application of the heat. Factors that preserve viability during heating are considered to be those which prevent coagulation of albuminoids and similar irreversible changes.

Witt, Paul R. Jr.- Effect of kilning on the amylolytic activity of barley malts. Cer. Chem. Vol. 22, No. 4, 341-349. 1945.

A pronounced increase in alpha-amylase activity was achieved by subjecting green barley malt to a "stewing" process in the top kiln (40° C. for 20 hours at a high moisture level) preceding final kilning. Beta-amylase activity was also enhanced, but to a lesser degree. (See also same reference under Use of Preservatives, Part III, p. 28.)

Use of Preservatives

Altschul, A. M., Karon, M. L., Kyame, Lillian, and Caravella, Maizie.- The storage of cottonseed. II. The effect of ammonia treatment on the free fatty acids and color of the seed oil, and on the rate and degree of heating of the seed. Oil and Soap, Vol. 20: 258-262. December 1943.

"Treatment of moist cottonseed with ammonia prior to storage has been shown to reduce self-heating of the seed and the rate of formation of free fatty acids during storage.

"The color of oils obtained by solvent extraction from ammonia-treated cottonseed is considerably lighter than that of oils obtained from untreated cottonseed."

Altschul, Aaron M.- The storage of cottonseed. III. Factors affecting the storage of moist cottonseed oil. Oil Mill Gazetter, Vol. 44. July 1944.

The author quotes others as saying that the safe upper limit of moisture content for cottonseed storage was 12 percent. Methods of preventing deterioration are discussed. (Bibliography included.)

Anderson, J. Ansel.- Effect of insecticides on wheat quality. pp. 29-30, Fifteenth Annual Report, Board of Grain Commissioners, Grain Research Laboratory, Winnipeg, Manitoba. 1942.

"Larvacide, Larvacide mixed with carbon-tetrachloride, Weevilcide, Weevil-Insecticide and Westofume all taint wheat, but the taints produced do not persist on subsequent aeration. It is believed that the amount of aeration produced by the normal handling of fumigated grain will be sufficient to reduce any taint to a level which is barely preceptible, even if twice the normal dosage of any of the fumigants is applied. Five times the normal dosage does not have any apparent injurious effect on either wheat strength or baking quality."

Back, E. A., Cotton, R. T., and Ellington, G. W.- Ethylene oxide as a fumigant for food and other commodities. Jour. Econ. Entomology. Vol. 23: 226-231. 1930.

"In ethylene oxide, when used as directed, we have a fumigant which, in addition to possessing freedom from the fire and explosion hazard and extreme toxicity to man, does not appear to leave in or upon the treated materials obnoxious odors, or residues

harmful to man or animals. It is believed that many commodities will be fumigated more successfully and with less danger when the details of application, particularly with carbon dioxide, have been worked out."

Balls, A. K. and Hale, W. S.- The effect of ethylene on freshly harvested wheat. Cer. Chem. 17: 490-94. 1940.

Small doses of ethylene very rapidly mature combine-harvested wheat so that it becomes suitable for bread making. Reliable data were not obtained pointing to accelerated metabolism, but it was considered probable that it occurs. Low concentration of ethylene increased the viability, but more was very harmful.

Franke, Erich - head of the production laboratory of the Fleischmann Yeast Company at Pekin, Illinois.- Observations, based on 15 years' experience in fermentation industries in Czechoslovakia and this country, on characteristics of stored grain.

In connection with the storage of potatoes for use by distilleries in the production of alcohol, it was found that the piping of carbon dioxide from the distillery to the storage bins prolonged the satisfactory storage period of the potatoes. This obviously slows down respiration and delays enzymic changes. (See also p. 14.)

Grain and Feed Journals.- Wheat treated with ethylene keeps better. Grain and Feed Jour., Vol. 88, No. 6, p. 267. March 25, 1942.

"Bin-burning of wheat having a high moisture content can be retarded by the use of ethylene gas in the storage bins, research workers of the U. S. Department of Agriculture and the Department of Milling Industry at Kansas State College have found. The gas, at a concentration of approximately one part in 10 thousand of air in the bin was blown into the bin while the damp wheat was being stored." ***

The treatment will reduce the rate of heating and will permit the farmer or grain handler to store high-moisture wheat for approximately two weeks, until it can be dried down to a safe moisture content.

"Wheat that was allowed to mature fully in the field before harvesting was also included in the ethylene storage research project. The investigators found that the gas apparently hastened the aging process through which wheat must go after harvesting before it will make flour of satisfactory baking quality."

Hale, W. S., Schwimmer, Sigmund, and Bayfield, L. G.- Studies on treating wheat with ethylene: I. Effect upon high moisture wheat. Manuscript from Enzyme Research Laboratory. U. S. Dept. of Agr., Bur. Agr. Chem. and Eng. 1942. Cer. Chem. 20: 224-234. 1943.

"As a rule, freshly harvested wheat neither bakes nor germinates well. A period of storage is necessary to bring either of these characteristics to the optimum level. Previously reported

experiments /Balls and Hale (1940)7 have shown that wheat, harvested while somewhat immature, underwent an almost immediate increase in baking test and germination capacity when exposed to air containing traces of ethylene. On the other hand, the flour from immature wheat (before treatment with ethylene) was not improved by subsequent exposure to the gas, although eventually it improved, like other fresh flour, on lengthy storage. Thus it seems the effect of ethylene on the baking test takes place in the whole grain. It is accompanied by a temporary rise in carbon dioxide output (frequently referred to as 'respiration'). Furthermore, the effect is not particularly pronounced on grain already aged in storage."

Two bins were filled with uniform high moisture wheat. One was treated with ethylene gas mixed in the proportion of approximately 10,000 parts of air to one of ethylene.

The investigations showed that application of ethylene to the freshly harvested high moisture wheat increased the rate of CO_2 evolution therefrom. The treated wheat did not heat as rapidly nor as much as the untreated. Grade of the grain, percentage germination, and baking performance of the treated samples were superior to the untreated during several months of storage. The experiment indicates that ethylene gas does not prevent spoilage of wheat stored with a high moisture content, but that heating of such wheat may be materially retarded.

Hoyt, L. F.- Further fumigation tests with ethylene dichloride--carbon tetrachloride mixture. Ind. and Eng. Chem. Vol. 20, No. 4, p. 931. September 1928.

"The food products after fumigation show different effects. Those rich in fat absorbed the fumigant appreciably but on exposure to the air gradually gave off the fumigant and became edible in 1 to 8 days."

Results of baking tests on Gold Medal flour showed, "There was no detectable difference in the odor, texture, or general appearance of these loaves, and although a faint odor of fumigant could be detected in the flour before use, the fumigant had had no effect on the quality of the gluten and could not be detected in the finished loaf."

Baking tests on whole-grain graham milled from fumigated grain indicated that, "No odor of the fumigant could be detected in the hot loaf when broken open--the most severe test."

Karon, M. L. and Altschul, A. M.- Effect of moisture and of treatments with acid and alkali on rate of formation of free fatty acids in stored cottonseed. Plant Physiol. 19: 310-25. 1944.

"The effect of the variation of moisture on the rate of formation of free fatty acid in cottonseed has been determined over a moisture range of 7.5 to 20 percent. (dry basis)

"Increase in moisture content of the seed results in an increased rate of hydrolysis of the glycerides. The most rapid increase in the hydrolytic rate was observed to occur when the moisture content was raised from 15 to 18 percent.

"Treatment of cottonseed with ammonia or hydrogen chloride gas was found to greatly retard the formation of free fatty acids. Treatment with ammonia retarded the darkening of the oil and in fact resulted in an oil with a much lighter color than that from the untreated seed."

Larmour, L. K., Clayton, J. S., and Wrenshall, C. L.- A study of the respiration and heating of damp wheat. Can. Jour. Res. Vol. 12, pp. 627-645. 1935.

"Respiration and heating studies were made on hard red spring wheat.

"Estimation of the true respiration of hard red spring wheat is complicated by the respiration of fungi which develop on damp wheat. The germination and growth of fungi can be controlled effectively by toluene or carbon tetrachloride vapor. In the presence of vapor of these substances carbon dioxide production goes on at a low rate and no heating occurs in wheat of 25 percent moisture content. The odor of the vapor disappears in the course of air-drying.

"Exposure of damp wheat to carbon tetrachloride for 25 days produced no deleterious effect on the quality."

Lubatti, C. F.- Sorption of fumigants. Nature, Vol. 155, p. 577. 1945.

Fumigants are sorbed very slowly by wheat. The main factors involved are (1) permiability of the seed coats, (2) diffusion and sorption in the endosperm, and (3) chemical reactions which may take place in the tissues of the grain. Increase in moisture content of the wheat brings about an increase in sorption of all the fumigants studied.

Oklahoma Agricultural and Mechanical College.- Agronomists experiment with fumigants for farms. Northwestern Miller. Vol. 211, No. 8, p. 16. August 19, 1942.

Agronomists from the Oklahoma Agricultural and Mechanical College have experimented with carbon disulphide as a fumigant. Because of its extremely high inflammable and explosive properties it is used for fumigation principally in a mixture with other fumigants or alone on a farm for treatment of grain in isolated bins. Workers found that the agent has no significant effect upon the germination or baking quality of wheat unless concentrations exceeding four times the recommended rate of approximately 4 gallons per 1,000 bushels are used. The agronomists state further that treatments heavy enough to affect germination also reduced loaf volume and changed the characteristics of the dough.

Ramstad, Paul E. and Geddes, W. F.- The respiration and storage behavior of soybeans. Univ. Minn. Agr. Expt. Sta. Tech. Bul. 156. 1942.

Toluene vapor prevented mold growth, but also caused loss of viability of the soybeans. Other reagents presented similar or equal difficulties. Surface sterilization techniques indicated that bacteria and fungi were present in the interior of the beans as well as on the surface.

Beans were heat sterilized, brought up to 19 percent moisture, and inoculated with water in which moldy soybeans had been shaken; a control was run with no inoculum. The incubation period was 9 days at 37.8° C., after which the CO_2 produced in 24 hours was measured. The inoculated sample produced 68.5 mg. of carbon dioxide, the other only 3.0 mg. The inoculated sample, therefore, reached a rate of respiration within the range expected for untreated samples under similar conditions of moisture content, temperature, and time of storage.

Split beans had much higher respiratory rate than whole beans, probably due to improved opportunity for fungus growth.

Above 13 percent moisture, rapid and irregular increases in respiratory rate were observed; these were considered to be due to growth of fungi and bacteria. These increases occurred during storage at moderate temperatures.

Rapid loss of viability was caused by conditions which favored the growth of microorganisms. To retain maximum germination capacity, soybeans should be stored at low moisture content (approximately 10 percent) and at as low a temperature as feasible.

Heating was studied in two types of adiabatic respirometers. Above 15 percent moisture, heating was observed. Time to reach maximum temperature decreased with increasing moisture. Aeration was found to be necessary for heating to take place.

Thornton, Norwood C.- Carbon dioxide storage. XII. Germination of seeds in the presence of carbon dioxide. Contr. Boyce Thompson Inst. 13 (7), 355-60. 1944. Biol. Abs. 18: 22890. 1944.

"Buckwheat, cabbage, delphinium, onion, pepper, pea, radish, sunflower, tomato, and wheat were tested for germination in CO_2 at 7 temperatures ranging from 5° to 35° C. From 40 to 80 percent CO_2 was necessary when 20 percent O_2 was present to inhibit germination of seeds except buckwheat, onion, and delphinium which were inhibited by 20 percent CO_2 only at 10° C. Cabbage, pea, sunflower, and wheat initiated germination in all concentrations of CO_2 at all temperatures except 5° and 10° C. where high concentrations retarded all but cabbage. The inhibiting effect was greatest at low temperatures, least at intermediate, and somewhat effective at highest temperatures."

Tremain, H. Earl.- The relative germicidal effectiveness of certain chlorine compounds on the thermoduric bacterial spores of wheat. Cer. Chem. 21: 511-15. 1944.

Sodium hypochlorite, chloramine B, and chloramine T at equal levels of available chlorine were approximately equally effective on the B. subtilis group.

Vlamis, J. and Davis, A. R.- Germination, growth, and respiration of rice and barley seedlings at low oxygen pressures. Plant Physiol. 18: 685-692. 1943. Biol. Abs. 18: 7315. 1944.

"Seeds of Sacramento barley and Carreon Upland rice were germinated aerobically and the respiratory activity of seedlings measured at several partial pressures of O_2. The O_2 consumption declined equally for rice and barley as the pressure of O_2 was lowered. The CO_2 production by both types of seedlings at 0.2 percent O_2 was about half that at 21 percent O_2. Barley seeds germinated at low O_2 pressures showed smaller percentage germination, inhibition of root and shoot development, and lower production of CO_2. Rice seeds germinated at low O_2 pressures yielded more shoot but less root development, and lower production of CO_2 than at 21 percent O_2."

Witt, Paul R. Jr.- Effect of kilning on the amylolytic activity of barley malts. Cer. Chem. Vol. 22: 341-349. 1945.

A sulfur treatment applied to green barley malt during kilning appeared to stabilize amylolytic activity against heat inactivation during the final phases of kilning.

Physical and Chemical Changes Occurring During Storage

Anderson, J. Ansel, Babbitt, J. D., and Meredith, W. O. S.- The effect of temperature differential on the moisture content of stored wheat. Can. J. Res. (c) 21, (10) 297-306. 1943. Biol. Abs. 18: 3230. 1944.

"Local increases in the moisture content of dry wheat stored in country elevator annexes have occasionally been observed in Western Canada. A laboratory experiment suggests that the chief cause is a temperature differential established during the winter. The air in the warmer parts of the grain contains a greater quantity of water vapor than that in the colder, and moisture is transferred either by diffusion or by the convective movement of the air as a whole. A temperature difference of 35° C., across 6 feet of grain having an initial moisture content of 14.6 percent caused the moisture content at the cold end (0° C.) to rise to >20 percent in 316 days. The experiment indicates that this movement of moisture is a slow process and that equilibrium conditions are never established for any practical length of time or mass of wheat."

Bailey, C. H. and Gurjar, A. M.- Respiration of stored wheat. Jour. Agr. Res. 12: 685-715. 1918.

"Deductions from these investigations support the findings of earlier investigators that spontaneous heating in damp grain is occasioned by the biological oxidation of dextrose and similar sugars, chiefly in the germ or embryo of the kernel.

"Soft, starchy wheats transpire more rapidly than hard, vitreous wheat with same H_2O content.

"Shriveled kernels respired 2 - 3x as much as plump wheat at >14 percent H_2O. Below 14 percent H_2O, the difference was not marked.

"Germ is supposed to be main site of respiration."

Bailey, C. H. and Gurjar, A. M.- Respiration of cereal plants and grains. IV. The respiration of frosted wheat plants. J. Biol. Chem. 44: 13-15. 1920.

Freezing and thawing increased respiration.

Bailey, C. H. and Bayfield, E. G.- Water imbibition of frosted wheat. Cer. Chem. 7: 108-116. 1930.

"Water imbibing capacity of entire wheat kernels was found to be related to their previous history. Those grains which were frozen when their moisture content was greater than 40 percent would imbibe more water than the normal or mature kernels. There was a high correlation between the amino nitrogen content of such wheat and the percentage of imbibed water. A survey of the data further indicates that the level of water content, on wetting the wheat, tended to return to that of the grain at the time it was frozen, when the latter was in excess of 40 percent. Thus, the imbibing capacity of wheat appears to afford an approximate measure of the extent of damage effected by premature freezing."

Bailey, C. H.- Respiration of cereal grains and flaxseed. Plant Physiol. Vol. 15, pp. 257-274. 1940.

Curves which represent the relationship between moisture content and respiratory rate of stored cereals are expressed mathematically. A comparison is made of small with plump or large kernels of barley. It was found that flaxseed respires much more vigorously than the cereals at all levels of moisture content in the range studied (11-17 percent).

Bakke, A. L. and Noecker, N. L.- The relation of moisture to respiration and heating in stored oats. Iowa Agr. Expt. Sta. Res. Bul. 165. 1933.

Molds found, also bacteria. "The difference in the number of kernels overgrown with molds may account largely for the variations in temperatures observed in the different samples." A sample with 5 percent kernels infested --> maximum temperature 27.06° C.; another with all kernels infested --> maximum temperature 35.20° C.

"Optimum temperatures for mold growth are approximately 30 to 35° C.; optimum moisture conditions exist between 24 and 40 percent depending upon aeration. With a decreasing moisture content the respiratory activity of both oats and associated microorganisms is lowered. In the case of oats under ordinary conditions of farm storage when the moisture content is below 15 percent, the respiration is so small that the heat produced is radiated."

Beckel, A. C. and Cartter, J. L.- The effect of variety and environment on the equilibrium moisture content of soybean seed. Cer. Chem. 20: 362-368. 1943.

"Approximate equilibrium moisture content of the seed of eight strains of soybeans grown at 5 locations in the North Central Region was determined at 3 relative humidity levels at 70° F. Significant variance was observed due to variety and location. Including all sample variance at each of the humidity levels, the standard deviation ranged from 0.163 at the low humidity level to 0.382 at 60 percent relative humidity.

"From data at 18 percent relative humidity and 70° F., it has been shown to be possible to eliminate the routine moisture determination without affecting the accuracy of the conversion of other analytical data to the dry basis."

Blish, M. J.- Effect of premature freezing on composition of wheat. Jour. Agr. Res. Vol. 19: 181-188. 1920.

"Frozen wheat contains larger amounts of nonprotein nitrogen, reducing sugars, and acid-reacting constituents than does sound wheat."

The nonprotein nitrogen of frozen wheat carries a considerably higher percentage of amino nitrogen than that of sound wheat.

Coleman, D. A. and Fellows, H. C.- Hygroscopic moisture of cereal grains and flaxseed exposed to atmospheres of different relative humidity. Cer. Chem. 2: 275-287. 1925.

Wheat, barley, buckwheat, corn, rice, rye, and flaxseed were studied and data are presented showing the moisture equilibrium for each at relative humidities ranging from 15 to 100 percent, 25 to 28° C. All except flaxseed had about the same hygroscopic properties. The equilibrium moisture content for flaxseed was appreciably lower. Moisture content does not increase at a uniform rate with the increase in relative humidity.

Coleman, D. A., Rothgeb, B. E., and Fellows, H. C.- Respiration of sorghum grains. U. S. Dept. Agr. Tech. Bul. No. 100. 1928.

"Storage tests made under laboratory conditions bear out in a general way the findings of the respiration studies; namely, that if the temperature is sufficiently high (100° F. or more) sorghum grains that contain over 14 percent of moisture will go out of condition."

Coleman, D. A.- Unsoundness in wheat. Grain Inspectors' Letter. June 13, 1931.

"The spoilage of wheat is the direct result of harvesting and storing of wheat with an excess of moisture. It makes but little difference whether the wheat is cut and stacked in a wet condition, or whether the wheat is threshed and stored with excess moisture, the ultimate results are the same. Stimulated by the high moisture content in the grain, rapid respiration or fermentation takes place, heat develops, with the result that the grain spoils, the extent of spoilage depending upon how long the wheat has been exposed to the fermentation process and how much heat of fermentation has developed."

Dubrovskaya, I. I.- Proteins of wheat exposed to frost in the field. Biokhimiya 9: 182-90. 1944. C.A. 39: 1677[1]. 1945.

Wheat from grain damaged by frost while still in the field contains proteins of smaller molecular weights than normal wheat proteins. The wheat subjected to frost contains fewer dicarboxylic amino acids. This is due to the unfinished development of the grain.

Franco, Coaraci M.- Estudos sobre a conservacão de sementes. I. Respiracão de sementes de algodão em diversas umidades relativas. (Preservation of seeds. I. Respiration of cottonseeds under various relative humidities.) Bragantia 3: 137-49. 1943. Biol. Abs. 18, 22900. 1944.

In studies of cottonseeds subject to relative humidities of 10-100 percent, respiration became noticeable above 80 percent Seeds held under relative humidities of 0-90 percent had moisture contents of 1.1-20.97 percent.

Geddes, W. F.- Chemical and physico-chemical changes induced in wheat and wheat products by elevated temperatures. These three articles form a thesis submitted to the faculty of the graduate school of the University of Minnesota in partial fulfillment of the requirements for the degree of Doctor of Philosophy. May 1929.

I. "Heat treatments of wheat and wheat products were conducted to study the influence of time, temperature, and moisture content."

II. Studies were conducted on heat-treated samples of unbleached straight grade flour milled from Eastern Canadian hard red spring wheat to determine the influence of time and temperature of heating flour with normal moisture content on certain biochemical properties related to "strength". Gluten quality was impaired in all heat-treated samples.

Chemical and physico-chemical changes in wheat and wheat products induced by elevated temperatures. III. The influence of germ constituents on baking quality and their relation to improvement in flour induced by heat and chemical improvers. Can. J. Res. Vol. 2, 195-213. 1930.

"It is concluded that heat treatment of flour is detrimental to gluten quality, but decreases the deleterious effect of germ

present in the flour. Unaged flours containing low grade mill streams may show an enhancement in baking quality by heat treatment, but the improvement will not equal that induced by chemical improvers which apparently act primarily on the germ constituent."

Geddes, W. F.- Factors affecting the keeping quality of grain. (Abstract of address given before the meeting of the Grain Elevator Superintendents at Duluth.) Grain and Feed Journals, Vol. 90, No. 12, p. 501-3. June 23, 1943.

"High moisture and high temperatures (up to about 55° C. or 131° F.) not only increase the respiratory rate of the grain and of microorganisms associated with it, but also favor insects. Dr. R. T. Cotton of the Bureau of Entomology and Plant Quarantine, U. S. Dept. of Agriculture, has pointed out that the common insect pests of stored grain cannot breed in grain containing 9 percent or less of moisture and the adults of many species soon die. Active breeding of most grain insects does not occur at temperatures below 70° F."

Geddes, W. F.- Factors affecting the keeping quality of grain in storage. American Miller 71 (8) 40, 93. 1943. Biol. Abs. 17: 24804. 1943.

"Respiratory activity exhibited by stored grain results from the respiration of the grain itself and of the bacteria, molds and insects which may be associated with it. Carbohydrates are the principal constituents oxidized. Respiratory activity of the germ of cereal grains is many times that of the endosperm. Moisture content is a major factor affecting the respiration intensity, and moisture contents exceeding those at which a break in the moisture-respiration curve occurs involve a great storage hazard. At equivalent moistures, oilseeds (soybean, flaxseed) have a much higher respiratory rate than cereal grains. Among the latter, rye has the lowest respiration. Cracked, shrivelled, immature, sprouted, frosted, and heat-damaged kernels respire more rapidly than sound plump grain of the same moisture content. High moisture and high grain temperatures (up to about 55° C.) increase the respiratory rate of the grain and of microorganisms associated with it, and favor insects. Accumulation of CO_2 in the interseed atmosphere depresses respiration. Movement of interseed air occurs in heating grain. Diffusion of warm-moisture-laden air from hot to cool areas may result in condensation of moisture on the cold grain, increasing the moisture content to a level favorable for active respiration of the grain and the development of microorganisms and insects."

Gilman, Joseph C. and Barron, D. H.- Effect of molds on temperature of stored grain. Plant Physiol. Vol. 5, pp. 565-573. 1930.

"The data gathered showed that under the conditions of the trials, the rises in temperature due to germination of oats, wheat, and barley, were 6.8°, 2.6°, and 3.6° respectively. A. flavus raised the temperatures of oats, wheat, and barley at 18 percent moisture content, 26°, 7.4°, and 16° C. respectively, A. niger

raised the temperatures of these grains 26.3°, 9.8°, and 21.9° C. respectively. A. fumigatus raised the temperature of oats at 18 percent moisture, 26.4° C. and wheat 5.2° C. At 20 percent moisture content, A. flavus and A. niger raised the temperature of wheat 15.8°, and 23.4° respectively. These facts strongly suggest the probability that in bins of stored grains marked increase in temperature may be ascribed to mold growth."

Grain and Feed Journals.- Sick wheat. Vol. 89, No. 1, p. 11. July 8, 1942.

"Sick wheat is but a new name for an old condition resulting from storage when damp. Prior to the advent of the combine when wheat was cut with the binder and stored in barns or stacks before threshing, sick wheat was usually referred to as mow-burned, stack-burned, header damaged. Each condition was usually accompanied by a musty or sour odor and such wheat was considered unfit for milling purposes. Briefly stated, the combine plus wet grain, plus storage, leads to heating, mustiness and enzymic action--result sick wheat."

Grain and Feed Journals.- Watch out for sick wheat. Grain & Feed Jour. Vol. 89, No. 3, p. 109. August 12, 1942.

"High moisture, and failure to turn wheat sufficiently during the early weeks of storage are the immediate causes of sick wheat. O. F. Phillips, Chairman of the Board of Review at Chicago, top grain supervision office of the U. S. Department of Agriculture says: 'Sick wheat is suffocated wheat. The germ of the wheat berry is a living organism. It breathes. When suffocated for lack of air, intermolecular respiration takes place. This breaks down the starch cells and the wheat starts to deteriorate. The germ turns color. It becomes gray, or reddish brown, or black. The bran coat is soon affected and the berry takes on a dead, lifeless, sometimes skin-burned appearance. If sick wheat is left to natural processes it becomes heat damaged. Eventually the whole berry will become black and charred.'"

"Sick wheat is not a new condition that has suddenly dropped upon us. It is merely another term for an old condition. Other terms used for the same thing in farm parlance are 'bin-burned', 'mow-burned', 'header damaged', and 'stack-burned'. Truth is that wheat so damaged was left to look after itself when it was too wet to do so. The result is sick wheat. That was how the federal department of agriculture officials looked at it back in 1925 when the term 'sick' originated."

Howe, R. W.- An investigation of the changes in a bin of stored wheat infested by insects. Bul. Ent. Res. 34: 145-158. 1943.

"The presence of warm spots in the bulk of grain will set up convection currents which tend to prevent the accumulation of carbon dioxide and renew the oxygen supply. Translocation of water over short distances will also be favored so that hot spots will tend to dry out a little and grain in the cooler regions nearest to the heating spots will become wetter."

Johnson, Arnold H. and Whitcomb, W. O.- A comparison of some properties of normal and frosted wheats. Montana Bul. No. 204. 1927.

"Wheat frosted when the moisture content is 44-46 percent or less appears to be equal in milling and baking quality to normal wheat even though the percentage of wrinkled or blistered kernels may be relatively high. Wheat of such moisture content is in the stiff-dough stage.

"No further translocation of proteins or carbohydrates into the kernels occurs when wheat has been subjected to a 'killing frost' but such translocation does occur in normal wheat cut 'young'.

"The crude protein content of frosted wheat appears not to be significantly different from that of normal wheat.

"The crude gluten in wheat is lowered by frost damage only when the grain has a moisture content greater than 44-46 percent at time of freezing."

Amino nitrogen compounds exist in greater quantity in frosted wheat and flour than in normal wheat and flour, and the ash content and reducing sugar content are greater in the frosted wheats and flours.

Jones, D. Breese, and Gersdorff, Charles E. F.- The effect of storage on the proteins of seeds and their flours. Soybeans and wheat. Proc. Am. Soc. Biol. Chemists. Vol. 9, No. 1, p. 49. 1939.

"Marked changes occur in the proteins of seeds on storage or aging, the extent varying with the kind of seed and conditions of storage. Although occurring much more rapidly in flours or meals, these changes also take place in the unground seeds.

"Defatted soybean meal stored for 1 year in bags at 24.4° decreased 18 percent in the amount of nitrogen extractable by 10 percent NaCl solution, 21 percent in digestibility, and nearly 12 percent in true protein value. Materially lower percentage changes occurred at -1.1°.

"Denaturation of the proteins of wheat and of wheat flours occurred to a much larger extent and more rapidly than that of the soybean proteins. After 1 month's storage in sealed jars at 24.4°, the nitrogen extractable from white flour by 3 percent NaCl had decreased 43 percent. At the end of 1 year, the percentage had dropped to approximately 50 percent. Large decreases in the amount of nitrogen extractable with 70 percent alcohol and Na salicylate also occurred, with similar changes occurring in whole wheat flour. Indications of extensive proteolysis in the wheat flours were shown by increased values in amino nitrogen and decreases in true protein values and in nitrogen precipitable by trichloracetic acid.

"Changes also occurred in the whole, unground wheat kernels. After storage in jars at 24.4° for 9 months, the percentages of nitrogen extractable by NaCl, alcohol, and sodium salicylate had decreased 26, 18, and 9 percent, respectively. Considerable proteolysis had also occurred."

Jones, D. B., Fraps, G. S., Thomas, B. H., and Zeleny, L.- The effect of storage of grains on their nutritive value. Seventh Report of the Committee on Animal Nutrition of the National Research Council, Washington, D. C., 14 pp. 1943.

Carotene content and other carotenoid pigments significantly decrease on aging and storage with a consequent loss of vitamin A activity. Thiamine (B_1) content does not seem to be greatly diminished by several years of storage under favorable conditions.

Fats in grain deteriorate with formation of free fatty acids, which may affect palatability.

Deterioration in the nutritive value of the proteins of grains may occur during storage, particularly if the grain is put in storage bins soon after harvesting. Protein values of freshly harvested ripe corn decreased rapidly during the first few weeks of experimental storage. After 12 months, however, no significant decrease in nutritive value was observed to have occurred during the second year. In these cases it is possible that deterioration was not observed because it had taken place before the samples were collected.

Jones, D. Breese, and Gersdorff, Chas. E. F.- Changes that occur in the proteins of soybean meal as a result of storage. Jour. Am. Chem. Soc. Vol. 60, No. 3, pp. 723-724. 1938.

Studies have been started to investigate the nature and extent of changes which occur in the proteins of seeds (both whole and ground) when stored under different conditions. Results thus far obtained show that marked changes in the chemical properties of the proteins of ground soybeans occur very soon after grinding. Some of these changes suggest a decrease in the biological value of the proteins.

*** "By the end of six months the digestibility of the protein of the low-fat meal stored in bags at 76° had dropped nearly 19 percent below that of the meal when freshly ground. The greatest changes occurred at 76°, although at 30° the changes were surprisingly high. Greater changes occurred in the meals stored in bags than in those stored in sealed jars. Of interest is the consistently greater changes that occurred in the low-fat samples than in the high-fat samples. The total nitrogen and free ammonium content of all the samples remained constant throughout the storage periods. The high-fat samples showed a slight increase in free fatty acids, particularly in the samples stored at 76°.

"Storage of soybean meal apparently results in partial denaturation of the proteins as indicated by their decreased solubility in salt solution. A proteolysis is also indicated by the drop in true protein values. The nature of the marked decrease in digestibility <u>in vitro</u> is being studied."

Kayukova, N. I.- Effect of carbon dioxide on the growth of molds which attack oilseeds in storage. Schriften. zentral. biochem. Forschungsinst. Nahr. Genussmittelind (U.S.S.R.) 3, 193-218. 1933. C.A. 28: 1561.

"The CO_2 accumulating from respiration of moist oilseeds inhibits mold growths. Higher CO_2 concentrations are more effective; at 80 percent CO_2 growth is very slow and at 90 percent it is practically stopped for molds, with only slight growth of yeasts and bacteria persisting. Decreasing the O_2 concentrations to 4 percent had no effect. Flaxseed is more susceptible than soybeans to preservation by CO_2.

Kelly, C. F., Stahl, B. M., Salmon, S. C., and Black, R. H.- Wheat storage in experimental farm-type bins. U. S. Dept. Agr. Cir. No. 637. 1942.

"Various measurements were used to determine the quality of the wheat during the storage period. The external evidences of wheat deterioration (such as percent total damage, test weight, odor, et cetera) usually were not apparent until the condition of the grain had been lowered enough to affect its commercial grade. However, percent germination and fat acidity of sound wheat were found to be valuable indices of incipient deterioration that is not apparent from grade examination, and graphs are presented to show the relation of percent total damage and percent germination to fat acidity through the range from 10 to 40 units of fat acidity. ***"

Kidd, F.- The controlling influence of carbon dioxide. III. The retarding effect of carbon dioxide on respiration. Proc. Roy. Soc. B89, 136-156. 1916.

Kidd showed that various concentrations of CO_2 in an anaerobic atmosphere depressed the respiration of germinating seeds in the same order as it did when oxygen was present. From this he concluded seeds to have two types of respiration, one depending on oxygen, and the other an anaerobic system, which was the one affected by carbon dioxide.

Kiesel, A., Vassilieva, N., and Tsygankova, G.- Translocation of moisture in the bulk of stored grain. Compt. Rend. (Doklady) Acad. Sci. U.R.S.S. (N.S.) 24: 786-790. 1939.

Showed that with insulated bulks of grain as small as 6 liters in volume a gradient of 12° C. in wheat containing only 9.8 percent moisture resulted in a moisture content of the cooler portion of 13.6 percent after 73 days. Gradients as small as 1 to 3 percent were shown to be effective in translocating moisture. In the high moisture areas so produced, molds proliferated and in some cases the moisture became so high that germination and bacterial rotting of the grain occurred.

Kretovich, V. L. and Rautenshtein, Ja. I.- Microbiological and biochemical processes in the self-heating of newly harvested wheat grain. Mikrobiologiia 10: 461-468. 1941. Biol. Abs. 17: 2172. 1943.

" A study was made of the changes undergone by two varieties of wheat seeds when stored in moist piles on a barn floor. With both varieties, the number of molds increased, and, when the temperature rose above 35° C. the germination capacity of the grain suffered. The catalase activity of the grain increased during the first hours of self-heating and then fell off sharply. Amylase activity decreased slightly at first and then increased. The elasticity of the gluten decreased with prolonged self-heating, while the titratable acidity of the alcoholic extract increased. Self-heating of grain evidently involves the activity of grain enzymes as well as the epiphytic microflora."

Larmour, R. K., Sallans, H. R., and Craig, B. M.- Respiration of whole and dehulled sunflower seed and of flaxseed. Can. Jour. Res. Vol. 22, Sec. F., pp. 9-18. 1944.

"The effects of various moisture contents on carbon dioxide production of whole and dehulled sunflower seed and of flaxseed were studied. The safe moisture limit for straight grading of whole, undamaged sunflower seed intended for bulk storage was estimated to be 9.5 percent; for dehulled sunflower seed it appears that 6 percent must be regarded as a maximum moisture for safe storage."

Larmour, R. K., Sallans, H. R., and Craig, B. M.- Hygroscopic equilibrium of sunflower seed, flaxseed, and soybeans. Can. Jour. of Research, Vol. 22, Sec. F., No. 1, pp. 1-8. 1944.

"Equilibrium moisture values for relative humidities of from 31 to 93 percent were obtained for sunflower seed, flaxseed, and soybeans. The hygroscopicity of whole sunflower seed per se is practically the same as that of flaxseed; that of dehulled sunflower seed is somewhat lower. Soybeans show a hygroscopicity curve quite different from that of flax and sunflower seed. The differences in these curves are not explainable by either the oil or ash contents of the seed."

Leach, William.- Studies on the metabolism of cereal grains. I. The output of carbon dioxide by wheat grains during absorption of water and germination. Can. J. Res. C 20: 160-8. 1942.

Germination is marked by three consecutive respiratory stages which are characterized by the rate at which the acceleration in CO_2 output occurs. These stages are (1) a slow rate of acceleration, (2) an increased rate followed by a decreasing rate, and (3) a final uniform and relatively high rate.

Water absorption rate under the experimental conditions did not appear to affect these stages. The infection of germinating grains by fungi reduces their respiration.

Leach, William.- III. The influence of atmospheric humidity and mould infection on the carbon dioxide output of wheat. Can. J. Res. C 22: 150-161. 1944.

"Under the experimental procedure used in these researches it was found that wheat, when kept at 25° C. in atmospheres of relative humidities between approximately 92 and 100 percent, showed a continuously accelerating rate of carbon dioxide output. This acceleration of rate increased as the relative humidity of the surrounding air was increased and was more pronounced in wheat from which the germs had been removed than in undamaged wheat where unlimited absorption of water and germination of the wheat are prevented, the carbon dioxide productions by the grain is due almost entirely to the respiration of microorganisms that infect it."

Mold growth more abundant as moisture content increased. When the grain cannot absorb an unrestricted amount of water (necessary for germination) the rise in CO_2 production of moist wheat is due to the respiration of the infecting microorganisms, which appear to be mainly fungi.

Leach, William.- Studies on the metabolism of cereal grains. II. The effect of age and kernel size on the cause of respiration of wheat during early germination studies. Can. J. Res. Sect. C. Bot. Sci. 21: 289-296. 1943. Biol. Abs. 18: 5408. 1944.

"Wheat samples that had been previously stored for periods of 6, 18, and 30 months were kept at 25° C. (a) in contact with water, and (b) in a moisture-saturated atmosphere for 40-hour periods during which hourly records of their CO_2 outputs were made. The lengths of the previous storage periods did not appear to have had any significant effect on the respiratory activities of the samples, but kernels of large average size gave a lower CO_2 output per unit weight of grain than kernels of small average size."

Leach, William, Moir, D. R., and Batho, H. F.- An improved arrangement for the measurement of carbon dioxide output of respiring plant material by the electrical conductivity method. Can. J. Res. C 22: 133-42. 1944.

Apparatus comprises an oscillator, amplifier, and vacuum-tube voltmeter which work in conjunction with a special type of absorption tube. Circuits are shown in diagrams. NaOH solution is used as the absorbing agent. An automatic recording set-up is described.

Miège.- The maturing of wheat and flour. Compt. rend. acad. agr. France. Vol. 19, pp. 636-9. 1933. C.A. 27: 4314^3. 1933.

"The effects of various types of storage on wheat and flour have been determined. The methods of storage tested have been: In bags, in bulk, kept covered at a temperature of 21°, in the air, day and night and in hermetically sealed bottles. Storage in bulk in the

air causes a general improvement of the quality of the wheat. This is due to a slow oxidation of the grain reserves which causes a diminution of the carbohydrates and a modification of the physical properties of the gluten. Under these conditions there is a lowering of the specific gravity and an increase in the moisture of the grain. Tenacity and baking value are greatly improved by storage."

Milner, Max.- The respiration and storage behavior of soybeans. Thesis submitted to the faculty of the Graduate School of the University of Minnesota in partial fulfillment of the requirements for the degree of Doctor of Philosophy. 1945.

*** "More severe than the damage to seeds by mold growth is that due to chemical heating beyond 50° C. Seed viability is destroyed at 45° C. As the temperature rises beyond 50° C. the chemical decomposition increases rapidly, manifested by increases in oil acidity, reducing sugars and nonprotein nitrogen. Probably as a result of oxidative and thermal polymerization of the seed oils, the petroleum ether extract falls drastically."

*** "An interesting phenomenon associated with the growth of molds on soybeans stored under ordinary conditions is the decrease in iodine value of the oil of the seed, as determined by measurement of its refractive index."

*** "Bacteria seemed to play little or no part in the respiration or heating of seeds having moisture values normally encountered in seed storage. *** Surface sterilization with mercuric chloride was ineffective in preventing respiration and heating, since molds would grow out from deep-seated infections within the seed."

Milner, Max, Warshowsky, Benj., Tervet, I. W., and Geddes, W. F.- The viability, chemical composition, and internal microflora of frost damaged soybeans. Oil & Soap 20: 265-268. 1943.

Seven composite samples of Minnesota grown soybeans and seven individual lots of Illinois soybeans of the 1942 crop containing varying percentages of immature and frost-damaged seeds were analyzed.

Increased damaged-seed content was accompanied by a marked decrease in viability and by increases in phosphate acidity, amino-acid acidity, nonprotein nitrogen, reducing sugars, and in the internal aerobic microfloral content of the seeds.

Proximate composition of the samples within each series showed little variation.

Newton, R. and McCalla, A. G.- Effect of frost on wheat at progressive stages of maturity. Can. J. Res. 10: 414-429. 1934.

"Susceptibility to superficial injury by frost continued generally over nearly the whole maturation period. Even 4 degrees of frost (28° F.) frequently caused a cut in grade, while 8, 10, and 14 degrees caused more substantial degradation, often accompanied by some reduction in weight per bushel."

Ramstad, P. E. and Geddes, W. F.- The relative respiratory rates and hygroscopic equilibria of common and hull-less oats. Jr. Agr. Res. Vol. 64: 237-241. 1942.

Respiration studies employing Gopher (common) and Nakota (hull-less) oats of high germinability and with test weights of 32-47 pounds per bushel, respectively, showed that, at the same total moisture content, the respiratory rate of Gopher oats per unit of dry matter was appreciably higher than that of Nakota, even under conditions which favor mold growth.

Gopher oats in equilibrium with atmospheres of different relative humidities were less hygroscopic (approximately 0.7 percent) than Nakota oats. This difference was shown to be due to the low hygroscopicity of oat hulls. At 70 percent humidity oat groats contained 13.8 percent moisture and oat hulls 12 percent.

Ramstad, Paul E. and Geddes, W. F.- The respiration and storage behavior of soybeans. Minn. Agr. Exp. Sta. Tech. Bul. 156. 1942.

"The lowest moisture content at which soybeans were observed to heat was 15.6 percent. Increases in respiration with time of storage were marked in soybeans containing over 13 percent moisture when stored at room temperature; furthermore, the iodine number of oil from such beans was greatly reduced, although the quantity of oil did not seem to be diminished. Soybeans remained sound and retained their viability well at a moisture content of 15.8 percent for a year and a half when stored at 4° C. On the other hand, when stored at room temperature, viability was seriously diminished even below a moisture content of 10 percent.

"Rapid loss of viability was caused by conditions which favored the growth of microorganisms in soybeans. Viability was better retained in beans stored at 15 percent moisture and a temperature of 4° C. than in beans from the same lot stored at 9 percent moisture and room temperature. To retain high maximum germination capacity, soybeans should be stored at a low moisture content (approximately 10 percent) and at as low a temperature as feasible."

Robertson, D. W., Lute, A. M., and Gardner, Robert.- Effect of relative humidity on viability, moisture content, and respiration of wheat, oats, and barley seed in storage. Jour. Ag. Res. 59: 281-291. 1939.

"The data showing the rates of change of moisture and viability with humidity offer a means of predicting the maximum time which would be safe for storage under any given relative humidity, assuming temperature conditions comparable to those of the experiment."

Sallans, H. R., Sinclair, G. D., and Larmour, R. K.- The spontaneous heating of flaxseed and sunflower seed stored under adiabatic conditions. Can. Jour. Res. Vol. 22, Sec. F., pp. 181-190. 1944.

"The effects of moisture content on the heating of flaxseed and sunflower seed were studied in an adiabatic thermostat. Under these conditions, storage periods of less than two months produced

heating in flax at 11.4 percent moisture and in sunflower seed at 10.5 percent moisture. Thus it appears that the commercial limits of 10.5 and 9.5 percent moisture, respectively, are not too low for these grains.

"Evidence is presented to show that an acceleration in the overall respiration rate of flaxseed and sunflower seed precedes heating. This indicates that heating is caused by active growth of the microflora on the grain and, at moisture levels in the order of those required for safe storage, normal embryonic activity is insufficient to cause heating.

"It is suggested that when the relative humidity of the interstitial air in bulk grain exceeds a value of 74 percent the microflora will grow and heating may ensue. From this it follows that the moisture content of any grain, in equilibrium with air at a relative humidity of 74 percent, will closely approximate the upper limit permissible for admission to 'straight' grades."

Sherwood, R. C., Andrews, John S., Wade, W. B., and Bailey, C. H.- The march of acidity in wheat germ during storage. Ind. Eng. Chem. 25 (4): 437-40. 1933.

Commercial wheat germ, granular in form, was sealed in tins and stored at different temperatures. The rate of increase in acidity depended primarily upon the temperature of storage. At 29° C. the average daily increase was of the order of 8 to 10 times greater than at -10° C. At 0° and 7° C. increase in acidity was greatly retarded and the germ remained in fresh condition for several months.

Simpson, D. M.- Relation of moisture content and method of storage to deterioration of stored cottonseed. Jour. Agr. Res. Vol. 50, pp. 449-456. 1935.

"Storage experiments with sea-island and upland cottonseed under the humid conditions prevailing at James Island, South Carolina, showed that in ordinary storage cottonseed deteriorates rapidly after two years. A definite relation is indicated between the moisture condition of the seed during storage and the rapidity of deterioration. Sea-island seeds, with a moisture content reduced below 8 percent, when stored in tin containers to prevent the rapid reabsorption of moisture, retained their germination percentage with only slight impairment for 4½ years. Upland cottonseed stored under various conditions and containing from 8.75 to 13.78 percent moisture deteriorated rapidly when the moisture in the stored seed remained above 10 percent. Dried seed stored to prevent reabsorption of moisture showed only slight deterioration after 2½ years. Seeds containing 13.78 percent moisture and stored to prevent drying were all dead nine months after the beginning of storage."

Smirnov, A. I.- The respiratory metabolism and enzymatic activity of the wheat kernel during ripening. Biokhimia 8: 149-157. 1943. Biol. Abs. 18: 7314. 1944.

"During ripening of the wheat kernel the energy of respiration decreases more rapidly than the water content. This decrease in respiration is accompanied by an increase of the r. q. The respiratory changes and the activity of dehydrogenases run parallel. The phenoloxydase and tyrasinase activity do not display any correlation with respiration. The decrease of the respiratory energy of the kernel during ripening conforms with the depletion of the respiratory substrate (sugar) and is caused by the decrease of amylase activity, with concurrent increase of the starch content. The acidity of the ethereal extract diminishes during ripening, indicating that the enzymatic activity is directed towards synthesis. The increased respiration of the unripe kernel is due to its humidity and the higher activity of the enzymes. This accounts for the lesser stability of the unripe kernels during storage, even after normal drying."

Smirnov, A. I.- Respiration of unripe grain and its storage. Compt rend. acad. sci. U.R.S.S. 44: 246-7. 1944. (In English).. C.A. 38: 1544. C.A. 39: 3570. 1945.

"The manometric method was used to study the respiration (I) of wheat at the early hard-dough and late hard-dough stage of maturity with varying percentages of H_2O. In grain of about the same H_2O content I is much greater in grain harvested at the early hard-dough stage than at the late hard-dough stage. The difference is more significant the higher the H_2O content of the grains being compared. I is very weak in grain harvested at the late hard-dough stage, when the H_2O content is reduced to 10-12 percent. The R. Q. of grain at the early hard-dough stage is below one, whereas at the late hard-dough stage it exceeds unity. The presence of such immature seeds, even though of a low H_2O content, may account, in part, for the spontaneous heating of dry grain in storage."

Sullivan, B. and Near, Cleo.- Changes of crude lipides of wheat on storage. Ind. Eng. Chem. 25: 100-3. 1933. C.A. 27: 783. 1933.

"Wheat and its products were extracted with various fat solvents and the P and N contents measured. Under different storage conditions the amounts of extracts showed marked variation. The data indicate that the changes observed are due to various fat-splitting enzymes, e.g., lecithinase. These enzymes show greater activity at the higher moisture levels and the changes are due largely to hydrolysis rather than to oxidation. An increase in acidity is correlated very definitely with increasing moisture content and with corresponding decreases in the P and N contents of the lipides. The lipide material extracted by all solvents shows a N:P ratio of more than 1:1; this indicates some N-containing compound other than lecithin in the extracts. Changes were most marked in those parts of the wheat highest in fat content and

in enzymic activity (germ and bran). Flours, patent and straight, showed only very slight changes in the amounts of lipides extracted by various solvents and in the P and N contents of the lipides, regardless of storage conditions."

Swanson, C. O.- Some factors involved in damage to wheat quality. Cer. Chem. 11: 173-199. March 1934.

"One of the best measures for the extent of damage which has taken place in wheat is the determination of the amount of acidity which has developed in the wheat fat. This is designated as rancidity. The development of this condition is, however, related to the air supply. In the entire exclusion of air this will not develop. Hence the conditions which favor the development of mold and rancidity are closely related. However, since damage to quality also took place in the sealed bottles, absence of high rancidity is not proof of lack of damage.

"Sugar was not increased until the moisture was above 18 percent. The diastatic activity was not increased by high moisture; on the contrary, the diastatic activity was greatest in the samples stored with low moisture. Thus it is not possible to increase either the sugar content or the diastatic activity by adding water in amounts which are safe for storage or in amounts used in tempering wheat."

Swanson, C. O.- Some factors which affect the diastatic activity in wheat. Cer. Chem. 12: 89-107. 1935.

Experiments on the influence of moisture content indicated that the sugar content and diastatic activity of wetted wheat did not increase the diastatic activity until the moisture percentage was sufficient to start the process of germination.

Swanson, C. O.- The effect of low temperature in preventing damage to wheat stored with high moisture content. Cer. Chem. 18: 299-315. May 1941.

"There was no decrease in viability in the samples stored in the cold (41° F.), while all those stored at higher moistures in the laboratory were dead. Wheat of good viability shows no damage to its milling and baking qualities. *** Wheat may be stored at 41° F. at high moisture for many months without suffering any damage to its milling and baking qualities. When wheat has good viability it has suffered no damage to the gluten structure even when a slight odor indicating unsoundness could be detected."

Swanson, C. O.- Effect of moisture on the physical and other properties of wheat. III. Degree, duration, and number of wetting treatments. Cer. Chem. 20: 286-299. 1943. Biol. Abs. 17: 20649. 1943.

"Samples of wheat which had not been exposed to rain were wetted to percentage varying from 14 to 26 percent and the wetting periods prolonged from 1 to 6 days at lab temperatures, and for 6 days at 45° F., samples were also wetted various times and amounts,

drying between wettings; wetting effects on Tenmarq and Chiefkan wheats were compared. The test weights were progressively decreased with increased amounts of wetting, and the vitreous condition was decreased and the mealy condition increased. The flour yield was not lowered by the decrease in test weight, due to wetting, nor by the duration of the wetting period, neither by the laboratory nor by the 45° F. temperature. The best baking results were obtained from samples wetted 23 and 26 percent for short periods. Wetting affected the mixing properties of dough in prolonging time of development, in decreasing the height of the mixograms. The number of times wetted had much less influence than the amounts of wetting. Neither the duration nor the temperature had any marked effects. The comparisons between Tenmarq and Chiefkan were not conclusive."

Thomas, R. C.- The role of certain fungi in the "sick wheat" problem. Ohio Bimonthly Bul. Vol. 22, No. 185, pp. 43-45. 1937.

"It is evident from this study that there is a great difference in the toxic effect of the byproducts of growth of various fungi, including molds, upon the viability of wheat. All of the organisms used have been found to be commonly associated with grains both in the field and in storage. This association becomes significant only when the moisture content of the grain is high and the temperature favorable for mold growth. Two strains of Aspergilli have been found to elaborate toxic products when grown upon bran. The toxicity of these products was demonstrated by the reduction of viability of normal wheat. What further changes these molds may cause in bringing about the condition known as 'sick wheat', rendering the grain inferior and milled products below standard, remain to be seen."

U. S. Dept. Agr. Clip Sheet No. 1253.- Store soybeans dry. Release July 5, 1942.

"Soybean seed stored in bulk sometimes loses viability--the ability to sprout--to a serious extent. Tests by the USDA in different regions indicate that this is mainly a matter of controlling the storage temperature and seed moisture. One lot of soybean seeds with 8 or 9 percent moisture, held at 35° F. for 8 years suffered no loss in viability, whereas another batch, with 13 or 14 percent moisture, held at 70° F., showed no germination after 20 months."

Whalley, Muriel E.- Abstracts on storage of grain N.R.C. No. 1011. National Research Council of Canada. 1941.

This is an excellent publication with abstracts from articles dealing with all phases of the storage problem.

Whitcomb, W. O., Day, W. F., and Blish, M. J.- Milling and baking studies with wheat. The effect of aging of wheat and flour on baking value. Mont. Bul. No. 147. 1921.

The results of experiments showed that the aging of flour made from sound wheat gave beneficial effects in all the factors considered while the aging of flour from frosted wheats gave a poorer loaf than when baked soon after milling.

By aging the frosted wheat, however, and then milling and baking a marked improvement in the loaf volume with little or no change in the other baking factors was shown.

Whitcomb, W. O., and Sharp, Paul Francis.- Germination of frozen and non-frozen wheat harvested at various stages of maturity. Jour. Agr. Res. 31: 1179-1188. 1925.

"Very immature wheat shows almost perfect germination.

"Freezing impairs the germination of wheat less the more mature the wheat is at the time of freezing.

"The germination of frosted wheat is greatly affected by aging. The germination is at first relatively low, increases with time to maximum, and then decreases to a low degree."

Zeleny, Lawrence, and Coleman, D. A.- Acidity in cereals and cereal products, its determination and significance. Cer. Chem. 15: 580-595. 1938.

"The Bureau of Agricultural Economics, in an effort to improve existing methods for evaluating quality of the cereal grains, has been making a study of acidity as a possible practical indication of deteriorative changes occurring in the grain." ***

"The acidic substances present in cereals and cereal products may be divided into three principal classes: (1) Free fatty acids, (2) acid phosphates, and (3) amino acids. These acids are present in small quantities in all normal grain and under certain conditions increase in amount chiefly by virtue of the enzymatic hydrolysis of fats, phytin, and proteins, respectively." ***

"A study of the individual acidity fractions in 246 samples of corn and of the same fractions in wheat undergoing deterioration in storage reveals the fact that only the fat acidity increases significantly during the early stages of spoilage." ***

"Fat acidity alone appears to be a more reliable index of soundness in grain than either of the other types of acid present, or than any combination of these acid fractions as determined by any of the commonly used methods."

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UNITED STATES DEPARTMENT OF AGRICULTURE
Agricultural Research Administration
Bureau of Agricultural and Industrial Chemistry

1945 SEMI-ANNUAL

NAVAL STORES REPORT

on

Production, Distribution, Consumption and Stocks

of

TURPENTINE AND ROSIN

of the

UNITED STATES

By Crop Years

April 1, 1945 - September 30, 1945

Issued November 19, 1945

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Compiled by

I. E. Knapp, L. A. Goldblatt

and M. M. Horner

Naval Stores Research Division

FOREWORD

This is the tenth Semi-Annual Naval Stores Report on production, consumption, and stocks of naval stores. Annual reports, covering the entire naval stores crop year, April 1 - March 31, are also issued. These reports are issued under Federal Act 278, authorizing and directing the Secretary of Agriculture to collect, compile and publish statistics and essential information relating to spirits of turpentine and rosin produced, held and used in the domestic and foreign commerce of the United States.

If production figures for this period are used as a basis for estimating this crop year's probable production, the fact that gum naval stores production is seasonal should be borne in mind. Wood naval stores production, on the other hand, is not seasonal but is based largely upon probable consumer demand and to some degree upon labor.

As in previous reports, carryover (stocks) of turpentine and rosin is separated into gum and wood products. Stocks of wood rosin do not include so-called "B wood rosin." While sulphate wood turpentine is carried in the regular production and carryover tables, data on tall oil ("liquid rosin") are in a table separate from gum and wood rosin. Pending the selection of a proper term, we continue to refer to the mixture of rosin and fatty acids recovered by the acidification of the soap curds (black liquor soap) obtained in the production of sulphate pulp as tall oil. The tall oil so obtained contains approximately 42 percent of resin acids.

The data on production, consumption and stocks are expressed in commercial units: For turpentine - barrels of 50 gage gallons; and for rosin - drums of approximately 520 pounds net weight. A unit of naval stores consists of one barrel of turpentine and two and two-thirds drums of rosin. Carryover figures do not include gum turpentine or rosin producible from crude gum on hand.

Statistics on exports and imports of turpentine and rosin are now available and are included in this report.

Tables 9a and 9b on pages 9 and 10 of this report are summaries of the supply and distribution of turpentine and rosin for the past eight crop years. Data on exports and imports which were not published during the war have now been released and are included in these summaries. For ready comparison, previously published rosin figures have been recalculated to drums of 520 pounds net weight.

These reports are designed to be of use to the industry — producer, factor, distributor, and consumer. Every effort is made to obtain complete and accurate information but the completeness, accuracy, and promptness of issue depend upon the cooperation of those reporting. In accepting the statistics given in this report, as well as those in previous reports, it should be borne in mind that the Bureau of Agricultural and Industrial Chemistry merely assembles the figures from the individual reports received and is not responsible for their accuracy.

The Bureau of Agricultural and Industrial Chemistry extends its thanks to those producers, factors, distributors, and consumers who have so kindly cooperated in furnishing the requested information. The assistance of Mrs. Clotilde H. Oubre in tabulating the data for this report is gratefully acknowledged.

SUMMARY OF TURPENTINE

SUPPLY, DISTRIBUTION AND CARRYOVER (Bbls. - 50 gals.)

(By naval stores crop years, beginning April 1 and ending March 31)

	1945-46 6 mos. (Apr. - Sept.)			1944-45 6 mos. (Apr. - Sept.)		
	Total	Gum	Wood	Total	Gum	Wood
TABLE 1a - SUPPLY AND DISTRIBUTION						
U. S. Carryover April 1 1/	202,546	168,011	34,535	295,581	262,057	33,524
Production 2/	281,124	158,981	122,143	269,439	159,312	110,127
Imports	8,896	8,896	---	8,390	8,390	---
Available Supply	492,566	335,888	156,678	573,410	429,759	143,651
Less Carryover September 30 3/	165,326	123,460	41,866	258,443	233,151	25,292
Appar. Total Consumption	327,240	212,428	114,812	314,967	196,608	118,359
Less Exports	51,146	42,032	9,114	43,735	35,508	8,227
Appar. U. S. Consumption	276,094	170,396	105,698	271,232	161,100	110,132
TABLE 2a - CARRYOVER (Stocks)						
U. S. Carryover April 1	202,546	168,011	34,535	295,581	262,057	33,524
U. S. Carryover September 30	165,326	123,460	41,866	258,443	233,151	25,292
Increase	---	---	7,331	---	---	---
Decrease	37,220	44,551	---	37,138	28,906	8,232

1/ From Table 4a, 1944-45 Annual Naval Stores Report.
2/ Table 5a.
3/ Table 4a.

SUMMARY OF ROSIN

SUPPLY, DISTRIBUTION AND CARRYOVER (Drums - 520 lbs. net)
(By naval stores crop years, beginning April 1 and ending March 31)

	1945-46 6 mos. (Apr. - Sept.)			1944-45 6 mos. (Apr. - Sept.)		
	Total	Gum	Wood	Total	Gum	Wood
TABLE 1b - SUPPLY AND DISTRIBUTION						
U. S. Carryover April 1[1]	388,266	265,881	122,385	794,786	648,206	146,580
Production[2]	774,481	431,055	343,426	728,736	426,310	302,426
Imports	9,326	9,326	---	2,578	2,578	---
Available Supply	1,172,073	706,262	465,811	1,526,100	1,077,094	449,006
Less Carryover September 30[3]	473,146	325,937	147,209	661,594	526,639	134,955
Appar. Total Consumption	698,927	380,325	318,602	864,506	550,455	314,051
Less Exports	64,678	30,272	34,406	145,343	120,084	25,259
Appar. U. S. Consumption	634,249	350,053	284,196	719,163	430,371	288,792
TABLE 2b - CARRYOVER (Stocks)						
U. S. Carryover April 1	388,266	265,881	122,385	794,786	648,206	146,580
U. S. Carryover September 30	473,146	325,937	147,209	661,594	526,639	134,955
Increase	84,880	60,056	24,824	---	---	---
Decrease	---	---	---	133,192	121,567	11,625

1/ From Table 4b, 1944-45 Annual Naval Stores Report.
2/ Table 5b. Includes reclaimed rosin.
3/ Table 4b.

DETAILS AND SUMMARY OF TURPENTINE CARRYOVER (Bbls. - 50 gals.)

TABLE 3a - DETAILS OF TURPENTINE CARRYOVER (Stocks)

	1945 September 30			1944 September 30		
	Total	Gum	Wood	Total	Gum	Wood
Production Points[1]						
Gum Stills[2]	25,503	25,503	---	26,490	26,490	---
Wood Plants						
Steam Dist.	5,931	---	5,931	5,864	---	5,864
Sulphate	6,598	---	6,598	4,725	---	4,725
Dest. Dist.	238	---	238	416	---	416
Total	38,270	25,503	12,767	37,495	26,490	11,005
Sou. Concent. Points[1]	72,847	72,847	---	178,748	178,748	---
Distribution Points						
Eastern	8,354	5,008	3,346	8,092	5,670	2,422
Central	14,145	9,761	4,384	14,363	11,843	2,520
Western	4,600	3,429	1,171	3,332	2,523	809
Total[3]	27,099	18,198	8,901	25,787	20,036	5,751
Industrial Plants[4]	27,110	6,912	20,198	16,413	7,877	8,536

TABLE 4a - SUMMARY OF TURPENTINE CARRYOVER (Stocks)

Production Points	38,270	25,503	12,767	37,495	26,490	11,005
Sou. Concent. Points	72,847	72,847	---	178,748	178,748	---
Distribution Points	27,099	18,198	8,901	25,787	20,036	5,751
Industrial Plants	27,110	6,912	20,198	16,413	7,877	8,536
Total in U. S.	165,326	123,460	41,866	258,443	233,151	25,292

1/ Irrespective of ownership. Some of the turpentine may have been sold and may be awaiting shipment.
2/ Compiled from reports by producers and factors.
3/ Compiled from reports of individual distributors.
4/ Compiled from reports of individual consumers.

DETAILS AND SUMMARY OF ROSIN CARRYOVER (Drums - 520 lbs. net)

TABLE 3b - DETAILS OF ROSIN CARRYOVER (Stocks)

	1945 September 30			1944 September 30		
	Total	Gum	Wood	Total	Gum	Wood
Production Points[1]						
Gum Stills[2]	88,696	88,696	---	106,824	106,824	---
Wood Plants						
Steam Dist.[3]	66,181	---	66,181	58,733	---	58,733
Sulphate	---	---	---	---	---	---
Dest. Dist.	---	---	---	---	---	---
Total	154,877	88,696	66,181	165,557	106,824	58,733
Sou. Concent. Points[1]	28,641	28,641	---	150,106	150,106	---
Distribution Points						
Eastern	10,929	5,538	5,391	9,677	7,234	2,443
Central	6,015	3,414	2,601	5,947	4,250	1,697
Western	922	383	539	641	263	378
Total[4]	17,866	9,335	8,531	16,265	11,747	4,518
Industrial Plants[5]	271,762	199,265	72,497	329,666	257,962	71,704

TABLE 4b - SUMMARY OF ROSIN CARRYOVER (Stocks)

Production Points	154,877	88,696	66,181	165,557	106,824	58,733
Sou. Concent. Points	28,641	28,641	---	150,106	150,106	---
Distribution Points	17,866	9,335	8,531	16,265	11,747	4,518
Industrial Plants	271,762	199,265	72,497	329,666	257,962	71,704
Total in U. S.	473,146	325,937	147,209	661,594	526,639	134,955

1/ Irrespective of ownership. Some of the rosin may have been sold and may be awaiting shipment.
2/ Compiled from reports by producers and factors. Includes reclaimed rosin.
3/ Does not include by-products resulting from making paler grades from FF wood rosin.
4/ Compiled from reports of individual distributors.
5/ Compiled from reports of individual consumers.

DETAILS OF PRODUCTION

(By naval stores crop years, beginning April 1 and ending March 31)

	1945-46 6 mos. (Apr. - Sept.)			1944-45 6 mos. (Apr. - Sept.)		
	Total	Gum	Wood	Total	Gum	Wood
TABLE 5a - PRODUCTION OF TURPENTINE (Bbls. - 50 gals.)						
Gum	158,981	158,981	---	159,312	159,312	---
Wood						
Steam Dist.	61,602	---	61,602	54,535	---	54,535
Sulphate	57,955	---	57,955	51,451	---	51,451
Dest. Dist.	2,586	---	2,586	4,141	---	4,141
Total	281,124	158,981	122,143	269,439	159,312	110,127
TABLE 5b - PRODUCTION OF ROSIN (Drums 520 lbs. net)						
Gum	426,505	426,505	---	423,810	423,810	---
Reclaimed Gum	4,550	4,550	---	2,500	2,500	---
Wood						
Steam Dist.	343,426	---	343,426	302,426	---	302,426
Sulphate	---	---	---	---	---	---
Dest. Dist.	---	---	---	---	---	---
Total	774,481	431,055	343,426	728,736	426,310	302,426

TABLE 5c - PRODUCTION OF BLACK LIQUOR SOAP AND TALL OIL[1]

	1945-46 6 mos. (Apr. - Sept.)	1944-45 6 mos. (Apr. - Sept.)
Black Liquor Soap Reported as produced	103,691 tons	96,828 tons
Black Liquor Soap Reported as acidified	101,644 tons	72,580 tons
To produce according to reports Crudo Tall Oil	49,591 tons	35,622 tons

1/ See foreword for definition.

TABLE 6 - PRODUCTION OF GUM TURPENTINE BY STATES[1/]

	1945-46 6 mos. (Apr. - Sept.)		1944-45 6 mos. (Apr. - Sept.)	
	Barrels	Percentage	Barrels	Percentage
South Carolina	1,267	0.80	1,329	0.83
Georgia	119,324	75.05	110,780	69.54
Florida	27,183	17.10	35,974	22.58
Alabama	8,710	5.48	8,791	5.52
Mississippi	1,832	1.15	2,020	1.27
Louisiana	665	0.42	418	0.26
Total	158,981	100.00	159,312	100.00

TABLE 7 - MISCELLANEOUS NAVAL STORES (Bbls. - 50 gals.)

	1945-46 6 mos. (Apr. - Sept.)	1945 Sept. 30	1944-45 6 mos. (Apr. - Sept.)	1944 Sept. 30
	Production	Stocks	Production	Stocks
Pine Oil	53,337	11,326	49,533	9,648
Pine Tar	43,377	4,806	43,964	1,227
Rosin Oil	10,457	2,548	11,856	2,291
Dipentene	9,567	4,024	8,859	2,312
Other Monocyclic Hydrocarbons	15,446	6,599	16,376	5,968

1/ A unit of naval stores consists of one 50-gallon barrel of turpentine and two and two-thirds drums (each 520 lbs net) of rosin.

TABLE 8a - REPORTED CONSUMPTION OF TURPENTINE IN UNITED STATES (Bbls. - 50 gal.)
(By naval stores crop years, beginning April 1 and ending March 31)

	1945-46 6 mos. (Apr. - Sept.)			1944-45 6 mos. (Apr. - Sept.)		
	Total	Gum[1]	Wood[1]	Total	Gum[1]	Wood[1]
Abattoirs	0			0		
Adhesives & plastics	162			231		
Asphaltic products	0			0		
Automobiles & wagons	97			102		
Chemicals & pharmaceuticals	55,595			64,985		
Ester gum & synthetic resins	9,400			5,905		
Foundries & foundry supplies	318			315		
Furniture	75			84		
Insecticides & disinfectants	8			105		
Linoleum & floor covering	21			22		
Matches	0			0		
Oils & greases	63			103		
Paint, varnish & lacquer	8,656			11,548		
Paper & paper size	0			0		
Printing ink	103			179		
Railroads & shipyards	4,950			5,414		
Rubber	449			244		
Shoe polish & shoe materials	5,568			6,678		
Soap	0			0		
Other industries	76			116		
Total industrial reported	85,541	17,351	68,190	96,031	28,328	67,703
Not accounted for[2]	190,553	153,045	37,508	175,201	132,772	42,429
Apparent U.S. consumption[3]	276,094	170,396	105,698	271,232	161,100	110,132

1/ Separation of gum and wood turpentine consumption will be limited for the present to the total reported.
2/ Principally unreported distribution of turpentine through retailers who sell in small quantities to ultimate consumers.
3/ From Table 1a, page 1.

TABLE 8b - REPORTED CONSUMPTION OF ROSIN IN UNITED STATES (Drums - 520 lbs. net)
(By naval stores crop years, beginning April 1 and ending March 31)

	1945-46 6 mos. (Apr. - Sept.)			1944-45 6 mos. (Apr. - Sept.)		
	Total	Gum[1]	Wood[1]	Total	Gum[1]	Wood[1]
Abattoirs	211			425		
Adhesives & plastics	11,566			14,335		
Asphaltic products	1,463			1,864		
Automobiles & wagons	67			136		
Chemicals & pharmaceuticals	138,304			131,747		
Ester gum & synthetic resins	131,758			111,515		
Foundries & foundry supplies	7,930			8,367		
Furniture	2			3		
Insecticides & disinfectants	3,035			3,924		
Linoleum & floor covering	4,349			10,804		
Matches	681			699		
Oils & greases	14,541			22,510		
Paint, varnish & lacquer	52,122			63,736		
Paper & paper size	133,233			188,654		
Printing ink	3,610			9,375		
Railroads & shipyards	8,813			11,502		
Rubber	12,881			8,662		
Shoe polish & shoe materials	2,995			3,508		
Soap	121,804			159,960		
Other industries	2,447			2,401		
Total industrial reported	651,812	361,986	289,826	754,127	453,736	300,391
Not accounted for[2]	-17,563	-11,933	- 5,630	-34,964	-23,365	-11,599
Apparent U.S. consumption[3]	634,249	350,053	284,196	719,163	430,371	288,792

1/ Separation of gum and wood rosin consumption will be limited for the present to the total reported.

2/ This discrepancy between the total industrial consumption reported and the apparent U. S. consumption is, no doubt, due in large part to errors in individual reports amplified by the change from the former barrel of 500 lbs. gross weight to the present drum of 520 lbs. net weight. Another factor may be the failure on the part of some consumers to distinguish between rosin and modified or derived rosins in their reports with a resulting duplication of reported consumption.

3/ From Table 1b, page 2.

TABLE 9a - SUPPLY AND DISTRIBUTION OF TURPENTINE

SUMMARY FOR EIGHT YEARS
(Bbls. - 50 gals.)

Crop Year, April 1 to March 31	1944-45	1943-44	1942-43	1941-42	1940-41	1939-40	1938-39	1937-38
U. S. Stocks at Opening of Crop Year, April 1	295,581	288,213	156,369	209,910	220,267	314,323	218,774	223,364
Production During Crop Year:								
Gum	245,194	288,382	321,930	285,050	343,938	382,781	534,291	518,454
Wood								
Steam Distilled	117,265	125,171	148,166	190,048	161,161	158,575	129,091	136,292
Sulphate	104,307	91,045	84,484	64,986	54,081	56,631	40,467	38,500
Destructively Distilled	4,477	3,834	5,771	8,712	7,161	6,791	5,369	7,085
Total Production	471,243	508,432	560,351	548,796	566,341	604,778	709,218	700,331
Imports	15,382	17,818	11,288	13,632	16,688	16,492	16,319	15,242
Total Available Supplies	782,206	814,463	728,008	772,338	803,296	935,593	944,311	938,937
U. S. Stocks at End of Crop Year, March 31	202,546	295,581	288,213	156,369	209,910	220,267	314,323	218,774
Total Disappearance	579,660	518,882	439,795	615,969	593,386	715,326	629,988	720,163
Loss Exports:								
Gum	49,780	26,812	21,872	79,447	103,127	189,684	174,908	233,371
Wood	15,483	19,072	20,808	33,523	27,728	48,754	35,309	42,929
Total Exports	65,263	45,884	42,680	112,970	130,855	238,438	210,217	276,300
Apparent U. S. Consumption	514,397	472,998	397,115	502,999	462,531	476,888	419,771	443,863

TABLE 9b - SUPPLY AND DISTRIBUTION OF ROSIN

SUMMARY FOR EIGHT YEARS
(Drums - 520 lbs. net)

Crop Year, April 1 to March 31	1944-45	1943-44	1942-43	1941-42	1940-41	1939-40	1938-39	1937-38
U. S. Stocks at Opening of Crop Year, April 1	794,786	1,284,229	1,147,742	1,499,328	1,255,517	1,297,577	799,478	530,601
Production During Crop Year:								
Gum	692,212	783,565	868,698	791,710	938,911	1,054,236	1,466,344	1,388,342
Wood	625,700	679,266	787,105	916,764	778,581	759,474	610,330	642,830
Total Production	1,317,912	1,462,831	1,655,803	1,708,474	1,717,492	1,813,710	2,076,674	2,031,172
Imports	17,238	4,340	1,211	1,651	1,788	2,326	284	272
Total Available Supplies	2,129,936	2,751,400	2,804,756	3,209,453	2,974,797	3,113,613	2,876,436	2,562,045
U. S. Stocks at End of Crop Year, March 31	388,266	794,786	1,284,229	1,147,742	1,499,328	1,255,517	1,297,576	799,478
Total Disappearance	1,741,670	1,956,614	1,520,527	2,061,711	1,475,469	1,858,096	1,578,860	1,762,567
Less Exports:								
Gum	160,092	311,007	189,576	342,935	220,337	471,076	401,013	591,707
Wood	55,591	143,680	139,560	233,411	203,473	309,628	256,212	235,542
Total Exports	215,683	454,687	329,136	576,346	423,810	780,704	657,225	827,249
Apparent U. S. Consumption	1,525,987	1,501,927	1,191,391	1,485,365	1,051,659	1,077,392	921,635	935,318

TABLE 10a - WEIGHTED[1] AVERAGE MONTHLY AND CROP YEAR PRICES OF GUM SPIRITS OF TURPENTINE - 1930-31 to 1945-46[2]

(Based upon Wednesdays and Saturdays Closing Savannah Prices)[3]

Crop Year	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Average
						Cents per Gallon							
1930-31	48.42	43.51	41.33	37.56	35.32	38.26	35.60	37.03	36.14	38.11	39.97	47.81	39.34
1931-32	50.44	49.42	50.69	39.77	31.40	31.88	31.17	35.21	33.83	34.68	34.84	40.06	40.10
1932-33	39.50	39.44	38.64	35.94	37.68	41.09	40.86	39.71	37.04	39.38	39.75	39.46	38.82
1933-34	37.88	42.47	40.39	46.39	42.83	41.97	40.81	42.14	42.07	47.44	57.00	55.00	42.72
1934-35	53.66	50.81	46.44	42.82	41.83	41.19	46.59	48.00	46.46	49.59	50.53	49.71	45.64
1935-36	47.37	47.07	44.46	42.40	38.47	40.91	45.76	44.92	43.96	45.19	44.44	39.31	43.56
1936-37	37.43	36.26	35.86	36.44	38.73	37.19	36.33	38.25	41.59	43.13	41.84	39.01	37.48
1937-38	35.97	35.83	34.07	33.44	31.94	29.93	27.28	26.92	26.14	28.18	26.47	25.42	31.36
1938-39	23.18	22.69	22.56	23.24	22.53	20.92	22.81	22.32	22.31	24.78	25.56	28.42	22.61
1939-40	24.96	23.93	24.00	24.11	23.72	26.11	27.16	25.72	27.00	30.17	32.91	31.67	25.31
1940-41	28.78	27.65	26.25	26.69[4]	28.69	30.80	34.99	38.37	37.11	42.05	38.78	39.25	30.03
1941-42[1]	42.11	43.00	42.17	48.28	67.83	74.84	78.08	75.61	73.44	75.89	75.19	73.08	63.85
1942-43	65.47	61.22	62.12	64.30	61.06	66.28	70.08	69.84	69.50	69.59	69.09	69.69	66.52
1943-44	69.46	69.47	72.08	72.77	73.03	72.14	74.53	81.60	80.87	83.03	83.59	82.60	76.26
1944-45	82.58	83.31	83.53	82.53	84.47	84.67	84.50	84.50	85.00	85.31	87.00	86.63	84.50
1945-46	86.16	86.83	85.44	80.93	82.19	83.44							

1/ Prior to 1941-42 monthly prices were obtained by averaging Wednesday and Saturday closing prices. The crop year average price was obtained by multiplying each monthly price by the combined reported receipts during that month at Savannah, Jacksonville, and Pensacola and dividing the total of these figures for the crop year by the total receipts for that crop year, thereby giving the months of heavy receipts and of low receipts their proper relative value. For 1941-42 and thereafter, only simple averages are shown.

2/ Prices for 1921-22 to 1930-31 crop years will be found in previous annual and semi-annual reports in this series.

3/ After November, 1936, Wednesday and Friday Savannah prices were used when there was no quoted Saturday market.

4/ Beginning July 1, 1940, quoted Savannah turpentine prices were exclusive of package. To complete this table and to present figures comparable with previous quotations, beginning July 1, 1940, 6 cents per gallon has been added to the Savannah quotations.

Sources of data: Florida inspections and monthly receipts at Savannah, Jacksonville, and Pensacola, The Naval Stores Review, Daily Market Reports of the Savannah Exchange, Jacksonville and Pensacola Chambers of Commerce and Economic Analysis Unit, General Crops Section, Agricultural Adjustment Administration.